ANNUAL REPORT OF PROGRESS

REHABILITATION ENGINEERING CENTER

OF

THE SMITH-KETTLEWELL EYE RESEARCH INSTITUTE

NIDRR Project Number G0085C3501

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1988

REPORT OF PROGRESS

REHABILITATION ENGINEERING CENTER

OF

THE SMITH-KETTLEWELL EYE RESEARCH INSTITUTE

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Core Area of Research:
Sensory Aids for the Blind, Visually Impaired, and Deaf-Blind

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A. VOCATIONAL AIDS

1. SKERF-PAD COMPUTER ACCESS SYSTEM

a. *Introduction*

We have been engaged in the development of a revolutionary new method of computer access for the blind, using a touch-pad to represent the computer screen. The user merely touches any part of the touch-pad, and a speech synthesizer enunciates the contents of the screen at the corresponding point. The new system, named the SKERF-Pad, greatly simplifies computer use by the blind.

Current computer access systems for the blind offer only indirect control, via keyboard, and require the learning of many, many arbitrary keyboard commands to "steer" the user around the screen and control the voice. The SKERF-Pad overcomes these problems using a system which is inexpensive in comparison to these other systems, and requires virtually no learning. Most of the system components - the speech synthesizer and the touch-pad - are available "off the shelf," and the only additional components required are a floppy disk containing the software and a thermoformed tactile overlay for the touch-pad (costing a few cents to produce).

b. *Recent Progress*

The current version of the system is now in use by several outside evaluators including a worker in the State Building in San Francisco, and Mr. Harvey Lauer of the Veterans Administration Blind Rehabilitation Center in Hines, Illinois. In addition, we have installed a SKERF-Pad on the IBM-compatible computer in our vocational laboratory, to allow its evaluation in daily use by our blind engineers. Mr. Thomas Fowle has been assisting in updating and debugging the system's software.

During the past year we have been making the SKERF-Pad program usable by a wider range of IBM-compatible computers - it will now work on PC, XT, and AT compatibles. It will work on color screens and on most networking systems, and can use either of two commonly available speech synthesizers. We have implemented other improvements including making the Pad accessible without calling it up from the keyboard, so that any touch of the Pad activates the reader. The use of variations in loudness, pitch, and other qualities of the synthesizer has been explored and implemented for the enunciation of bold print, underlining, and other features of the text as displayed on the screen.

A most significant additional development is the new touch-pad overlay (*Figure 1*), produced by vacuum thermoforming methods from a mold constructed to our design by Litzaw Engineering, Inc. The new overlay gives the device a very professional "look." It guides the user's fingers along the lines of the "screen" via raised tactile markings, delineates the positions of individual characters, and provides a column of tactile "switches" for the control of various features of the system.

The SKERF-Pad has been demonstrated at conferences in Southern California and Montreal, and at Philadelphia's Associated Services for the Blind Computer Workshop and the Hi-Tech Center in Sacramento. Our contractor on this project, Mr. William Loughborough, has made the current version of the system commercially available for a price of $500 including the touch-pad, overlay, and software. Meanwhile, other options are being explored for larger scale commercialization.

Figure 1. New Touch-Pad Overlay (bottom) and Mold (top).

2. SMITH-KETTLEWELL VOLATILE BRAILLE DISPLAY

Our new low-cost refreshable electromagnetic braille display has moved rapidly toward completion. A patent is now pending on the system, and two major sensory aids manufacturers (one in the United States and one overseas) have been engaged, ahead of schedule, in the commercialization process.

In view of the manufacturers' enthusiasm for early involvement in the project, it was not necessary for us to construct a 20-cell version at our own expense. Instead, we have fabricated two additional 3-cell prototypes for evaluation by the manufacturers in their process of product development. Several areas of potential further improvements have been identified in our laboratory tests. We have designed an 8-dots-per-cell version, and investigated potential methods of reducing power consumption.

A principal advantage of the design is the extremely low parts count; however, since the electromagnetic activation requires a separate coil for each braille pin, optimization of coil design and identification of potential sources is a current priority. We are providing engineering assistance as needed to the manufacturers. We are retaining one prototype in our laboratories for continued testing and for resolving any problems encountered in the process of pre-production engineering.

3. FLEXI-METER

The engineering prototype of the Flexi-Meter (our microprocessor-based job instrumentation system for the blind) has been substantially modified and upgraded during the past year. The firmware has been expanded to utilize most of the hardware capabilities and to provide the ability to give desired outputs from a wide variety of instruments. Tests have been done on connecting the unit with various commercial transducers. As a demonstration of the unit's flexibility, the system has been adapted to read a wind direction and speed meter, and it has been fitted with a custom thermometer and barometers. Thus the unit now incorporates a basic talking weather station (*Figure 2*). The ability to make the weather station adaptation in a short time period (prior to the 1988 RESNA conference) has confirmed the Flexi-Meter's potential as a customized instrumentation system for measuring any parameter.

Figure 2. Flexi-Meter Interfaced to Weather Station

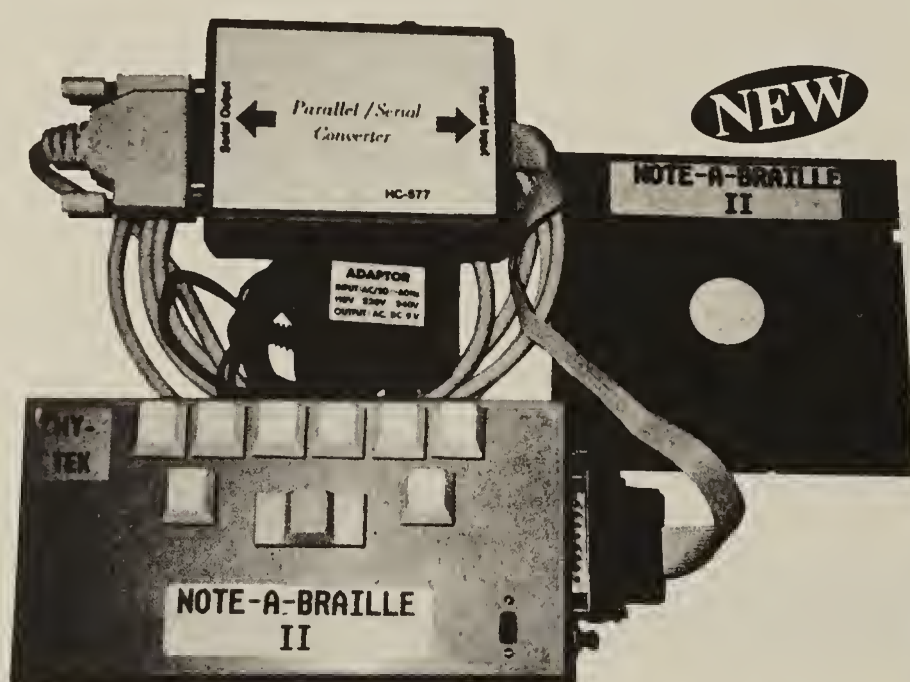
The unit has been demonstrated to a number of blind persons, both at the RESNA conference and in our laboratories, and their feedback has been taken into consideration in the design of the eventual production unit. Only minor physical design changes were considered necessary by those who have tested the unit, and those changes will be incorporated into the final version. A field trial of the Flexi-Meter in an outside work setting was scheduled but had to be postponed due to the illness of our subject, Mr. Randy Brooks.

The production engineering stage of the Flexi-Meter is now beginning. Serious consideration has been given to the best means of making the device commercially available, and discussions with manufacturers and others have led to the conclusion that the most satisfactory outlet, at least initially, will be our privately funded Rehabilitation Engineering Service, since some degree of individual tailoring (of software and/or hardware) will be needed in many of the potential applications - particularly in the early production phase as the range of commercial transducer interfaces and applications is expanded to its full potential. We anticipate being able to complete a production prototype in 1989. Our test results to date confirm our feeling that the advent of the Flexi-Meter will represent a major breakthrough in expanding employment opportunities for blind individuals.

4. BRAILLE NOTE TAKER

Our Note-a-Braille project has been completed as scheduled. Two versions are now commercially available: one manufactured in the United States and one in England.

In the Spring of 1988, HY-TEK Manufacturing, Inc. of Sugar Grove, Illinois, began marketing the "Smith-Kettlewell Note-a-Braille II." This version of the device comes with a parallel-to-serial converter (needed for most standard brands of computer) and has an expanded memory of 16K. It is being offered in the latest catalog of the LS&S Group, Inc., Northbrook, Illinois (*Figure 3*).



Affordable

NOTE-A-BRAILLE II

Portable Note Taker

Based on the original design from the Smith-Kettlewell Eye Foundation, the Note-A-Braille II takes meeting notes in Braille and saves them in RAM memory. Easily connects to your personal computer (IBM, Apple, or compatible with a standard RS232 interface) and load your notes into your computer. The notes are converted from Braille into ASCII as they are loaded. Now, use the computer to edit, print or read the notes to you using your own screen review program and text-to-speech device. Compact 7-1/2" x 4" x 1-1/2" size. **Unit comes complete with: parallel to Serial converter with AC adapter, serial interface cable, communication software, earphone, battery, instruction diskette and carrying case.** Either Grade I or Grade II Braille can be used for data input, but bi-directional translation software is required for Grade II conversion. Battery life is a minimum of one month. The audible "clicks" that are heard with each keystroke—begin to occur on every other keystroke as the RAM limit is approached. One year warranty.

Model 202-NAB-II
$395.00

Figure 3. Commercial Version of Smith-Kettlewell Note-a-Braille
(Excerpt from LS&S Catalog, 1988-89)

The English version is being made by the manufacturers of the Brade Speech Synthesizer in England. It is ideally suited to the very popular BBC computer; no converter is needed to interface the Note-a-Braille's natural parallel port to a serial port on the BBC instrument.

The successful conclusion and commercialization of this project has resulted in a unique, low-cost electronic braille note-taking system being made available to the blind. The design offers an affordable alternative to the expensive special-purpose braille word processor/computer systems.

5. GENERAL-PURPOSE STORED-SPEECH BOARD ("RAM-TALKER")

A new project this year has been the development of an inexpensive general-purpose add-on speech module.

We have long seen the need for an addressable limited-vocabulary speech board to exist as a component of talking devices. A generic voice module (using a commercial synthesizer chip) is made by AFB and marketed as the GVM. This is useful for adapting certain commercial products that have a suitable signal output to drive it; however, application of the GVM is limited to a particular class of special modification. A more general approach is needed to fulfill the following functions.

First, it appears that the product life of speech boards for commercial applications has been shorter than that of talking devices for the blind. With the demise of both the TSI "Mini Speech Board" and the National Semiconductor "Digitalker" chip set, useful talking meters and calculators have disappeared with them. (There is now a crisis in the area of talking instruments for the blind: no talking multimeter is currently available, even though the demand for such meters numbers about 150 per year.) Our "generic" unit will always exist, since it is made from the most basic computer memories and logic chips.

Second, such a component will not be language-specific. Its vocabulary is loaded by speaking into a microphone; in fact, one version, which we recently described in detail in the *Smith-Kettlewell Technical File*, includes the ability to record the speech yourself. (The do-it-yourself version uses a battery-backed RAM; it is trivial to make a non-volatile version recorded in the laboratory.) Although the current design contains fourteen chips, most of these cost less than a dollar, and the eventual price will be low.

A sixteen-word, randomly accessible speech module (*Figure 4*), named the "RAM-Talker," has been developed and tested, and its design published in the *Smith-Kettlewell Technical File*. Along with a Technical Devices voltmeter chip, the device will make it possible to replace the defunct talking multimeters (work is now proceeding on this multimeter application). In addition, details on a first-in first-out (FIFO) buffer have been published in our *Smith-Kettlewell Technical File* so that others, including the enterprising blind do-it-yourself'er, can use the "RAM-Talker" to make other talking instruments.

Overall, our "RAM-Talker" module should make conversions of instruments to speech output practical, inexpensive, and not subject to obsolescence of specific commercial speech synthesizers.

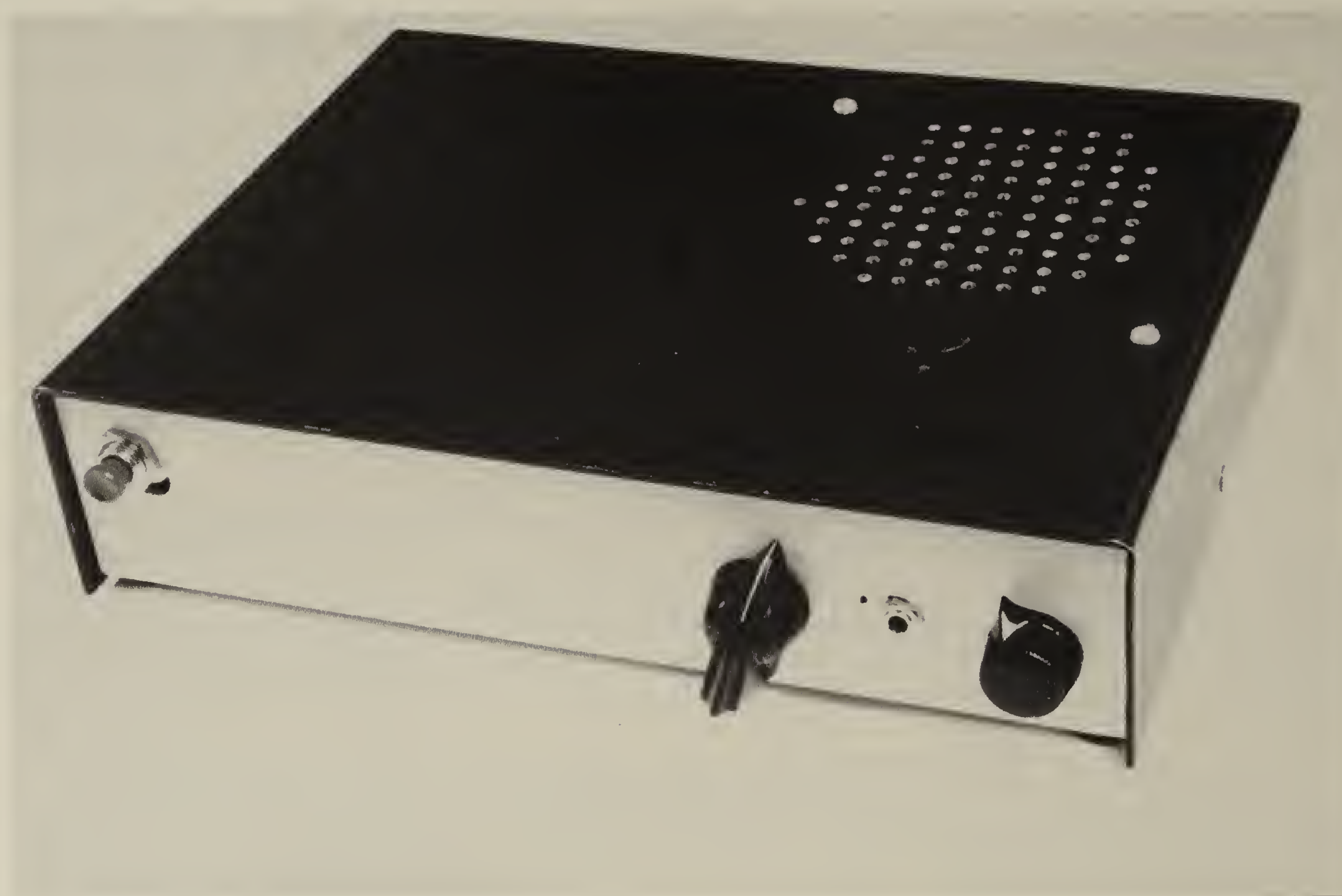


Figure 4. Smith-Kettlewell RAM-Talker

6. SPECIALIZED AIDS AND DEVICES

a. Temperature-Controlled, Quick-Heating/Fast-Cooling Soldering Iron

A successful temperature controller for the so-called "Fingertip Soldering Iron" has been designed, evaluated by our three blind laboratory workers, and published. Three prototypes have been built for field evaluation.

A rudimentary design for this fingertip iron was submitted in writing by Bernie Vinther, a reader of the *Smith-Kettlewell Technical File*. It uses a soldering tip from a "cordless" battery iron to make an extremely light-weight iron which puts the user's fingers close to the work - thus enhancing facility in handling the device. A further advantage is that such a tip can be placed on the work when it is cool, then energized by way of a foot control.

A serious disadvantage of the original instrument was that frequent overheating of the tip was inevitable. Our newly designed temperature controller completely solves the problem; the tips last longer, and damage to the work is now infrequent. The controller works by measuring the resistance of the tip, which is an element of a Wheatstone Bridge (*Figure 5*).

The new design is published in the *Smith-Kettlewell Technical File*, and ideas for yet further improvement will, no doubt, be forthcoming in the "Technical Forum" section of that publication. One possible enhancement would be to design a small high-current socket to make tip replacement trivial. (Currently, a new tip must be soldered to the end of its cable.) In any case, the viability of this tool is assured. Mr. Vinther is planning to manufacture the device.

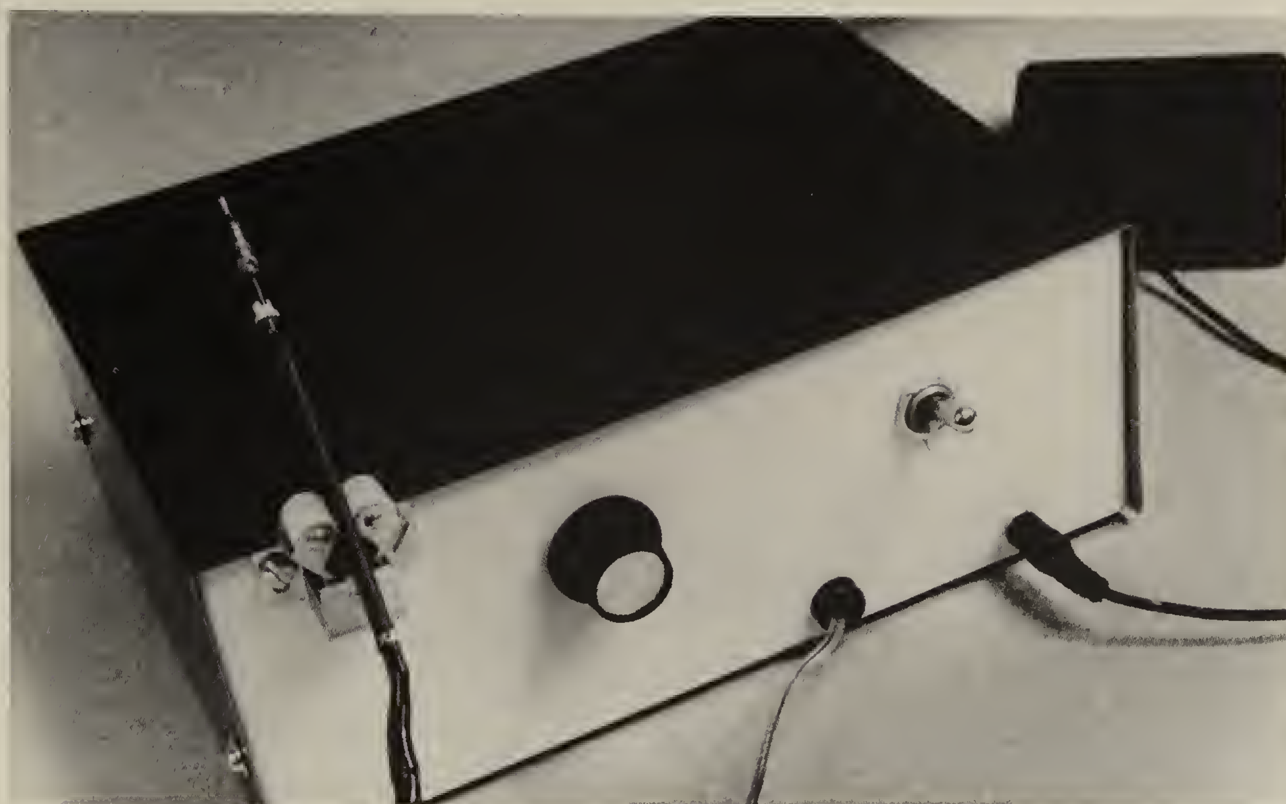
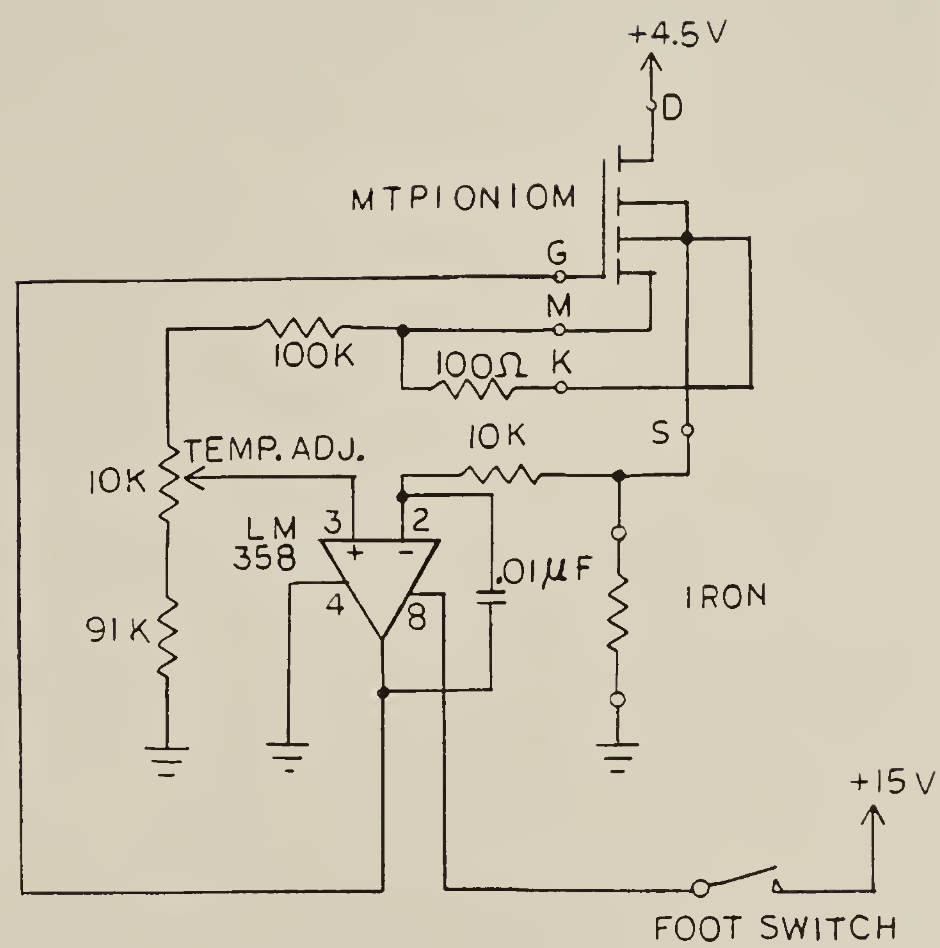


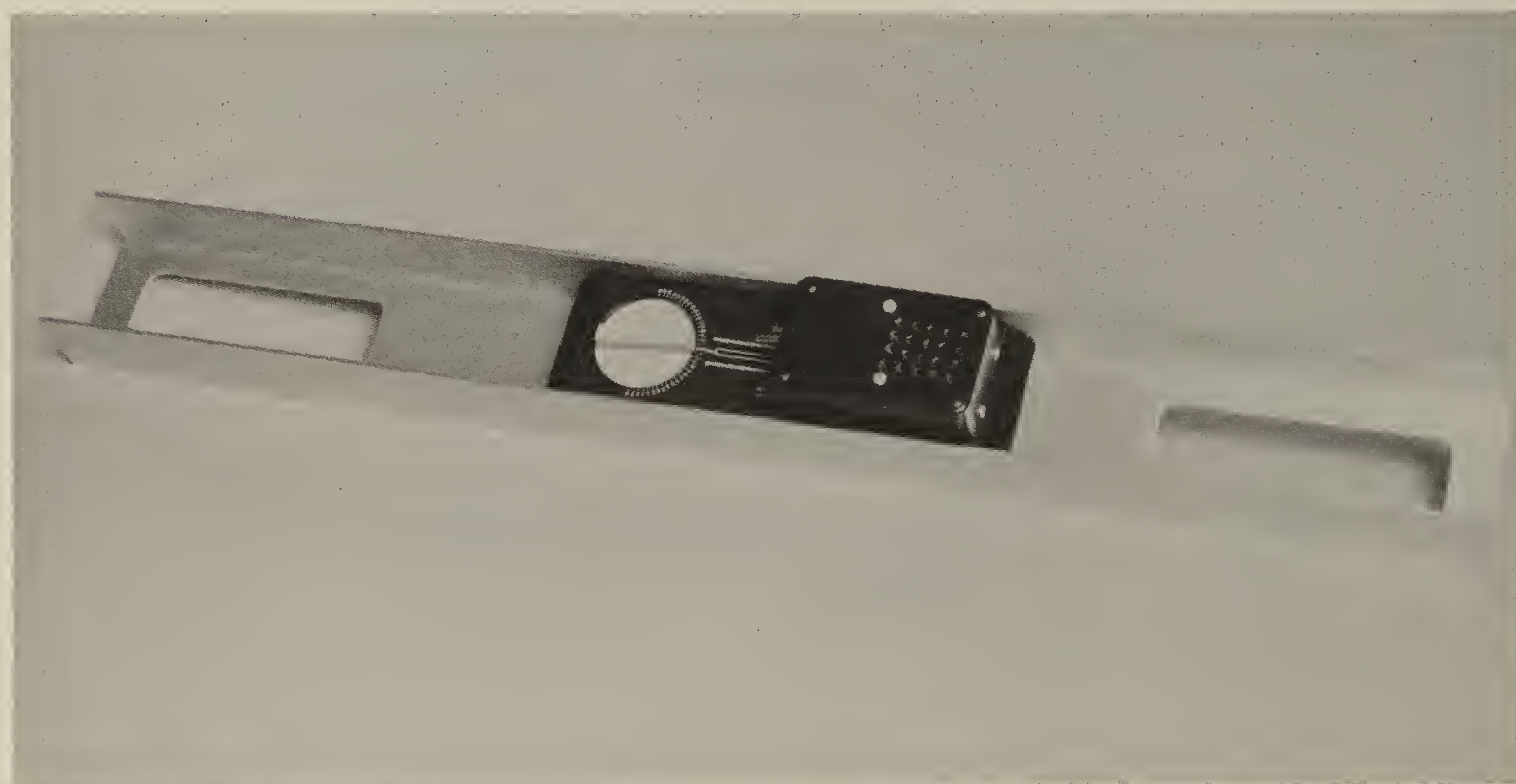
Figure 5.
Temperature-Controlled
Soldering Iron
and
Schematic



b. <u>Carpenter's Level</u>

Our project to develop an improved Auditory Carpenter's Level is being successfully concluded. As described in last year's report, we had identified a commercially available electronic level which lends itself to convenient adaptation for the blind. Difficulties and design alterations accompanying a take-over of the original level manufacturer by another company were resolved.

This year, four prototype levels (*Figure 6*) were duly constructed and distributed as planned, and the feedback was all positive. Three of the subjects purchased their units through our privately funded Rehabilitation Engineering Service.



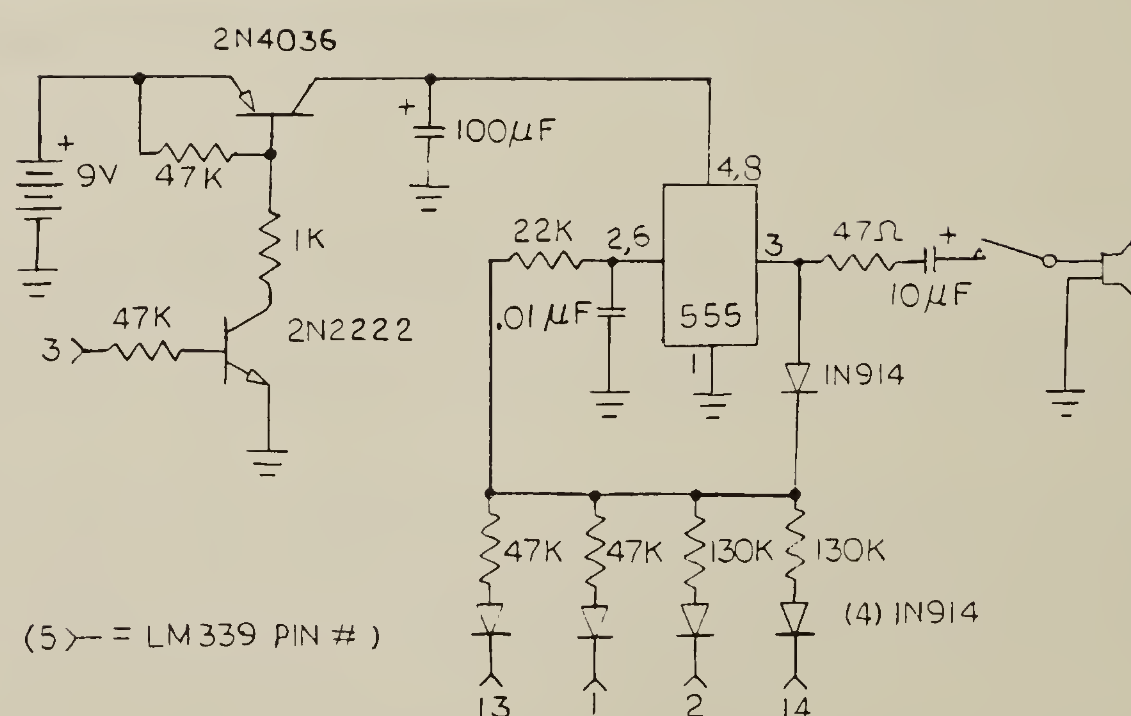


Figure 6. Auditory Carpenter's Level and Schematic

Also this year, engineers from the National Research Council of Canada visited our laboratories for an extended period to study our vocational engineering methods and our circuit construction techniques for blind engineers. After reviewing our circuits for the level (including information we obtained through "reverse engineering"), they derived a simplified version which they intend to implement for producing equivalent units.

Our original approach had been to make all of the visual level's LEDs audible to the blind user; this was done by way of an external oscillator that generated four different pitches. The simplified approach being adopted by the Canadians for the production units is to modify the response of an internal beeper; the level will emit a solid beep at one side of "level," silence will occur on the other side of "level," and the beeper will pulsate when the desired position is attained. A survey of our users suggests that this arrangement would be slightly less preferable to our audible presentation (it will not indicate the degree of tilt, for example), but that the new version would be adequate. The production version should, however, be less expensive than our earlier, more comprehensive version.

c. *Stud Finder*

A common problem encountered by custom cabinet makers, as well as individual homemakers, is finding the structural members within walls ("studs") onto which heavy shelves and wall hangings can be mounted. There have been many devices for finding "studs," but these are traditionally visual instruments. We have successfully modified a commercial stud finder so as to present auditory feedback to the blind cabinet maker and handyman.

The Zircon "Stud Sensor" (also marketed by Radio Shack as the "Archer Studfinder") is a sophisticated electronic device whose indications of hidden structures are not subtle. It is a relative capacitance meter which senses these structures by their capacitance effect; it presents these relative indications to a sighted user via a column of LEDs. By reverse engineering, a "relative capacitance" analog signal was found which can be used to drive a voltage-controlled oscillator (VCO). Thus, with our modified instrument (*Figure 7*), the blind user hears a distinct rise in pitch when the capacitance increases - which happens when a stud is found.

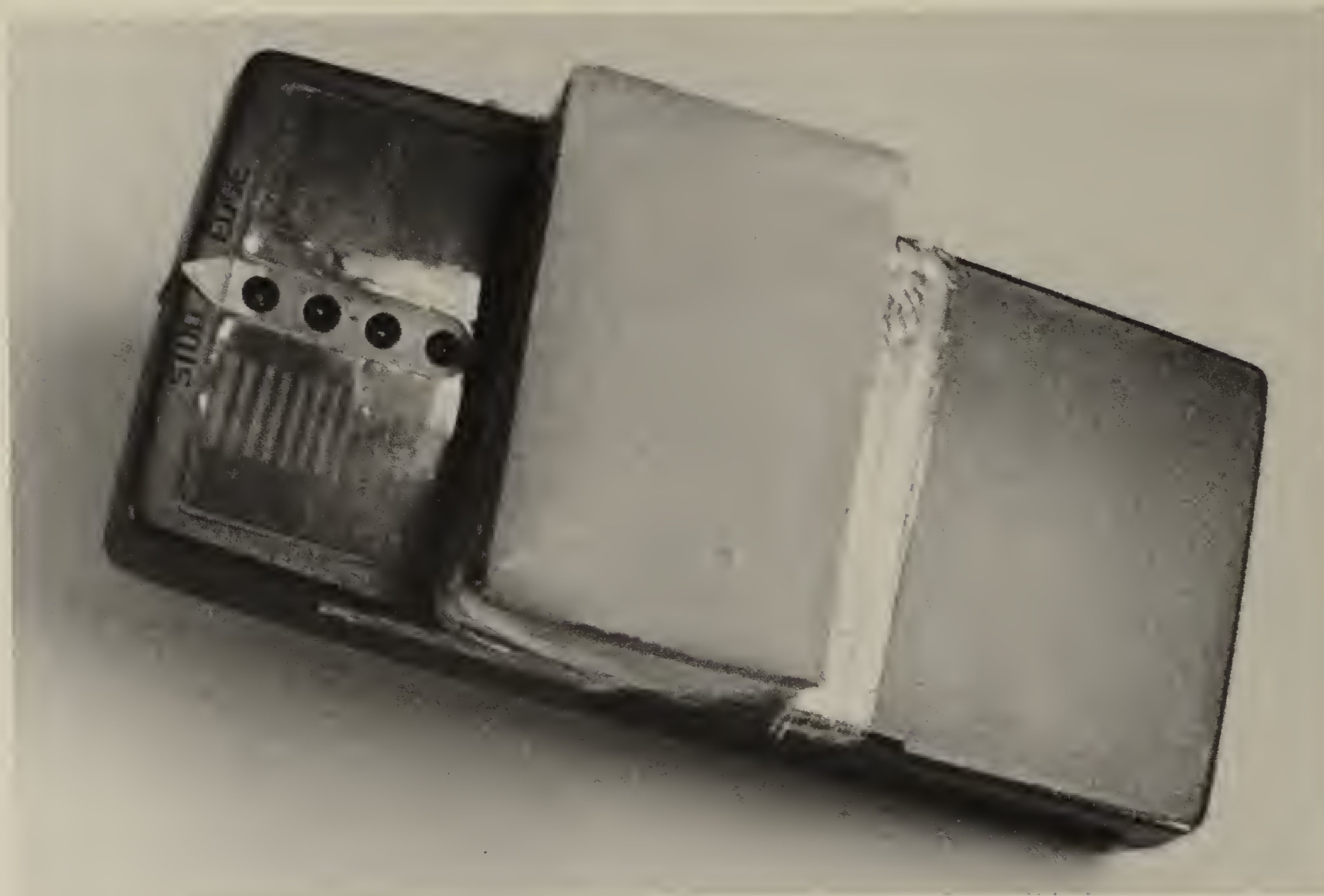
Four prototypes are being made for field trials. The device will be made available through our privately funded Rehabilitation Engineering Service if user feedback is positive. The modifications have been published in the *Smith-Kettlewell Technical File*, and individuals who have made their own from our design have applauded the instrument's utility.

d. *A Non-Damaging, Low-Resistance Ohmmeter*

Traditionally, ohmmeters for the blind have used a Wheatstone Bridge whose output was simply detected auditorally. (The bridge configuration has a traditional preference, since its output is "linear"; the output of other ohmmeters is not.) The problem with this technique is that low resistances under test are subjected to high currents (as much as 1 amp for a 1-ohm resistor). While necessary to make the bridge output sufficiently audible, these high currents can be damaging to modern components, and such an instrument cannot safely be used for tracing circuit boards (which is a significant loss for the blind service technician, who cannot trace circuit boards by eye).

Using a sensitive comparator chip, the National LM311, we designed an audible Wheatstone Bridge circuit that subjects its test element to 10mA, maximum. Furthermore, it is silent until a test resistance below its preset threshold is present across its terminals. Thus, not only will it serve as a much-needed ohmmeter, but tracing of moderately sensitive circuitry is now possible.

The device (*Figure 8*) has been successfully built and tested, and is being published in the *Smith-Kettlewell Technical File* as well as added to the range of products of the Rehabilitation Engineering Service.



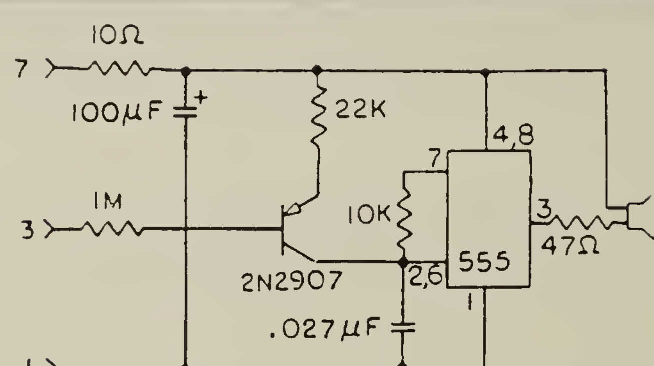


Figure 7. Auditory Stud Finder and Schematic

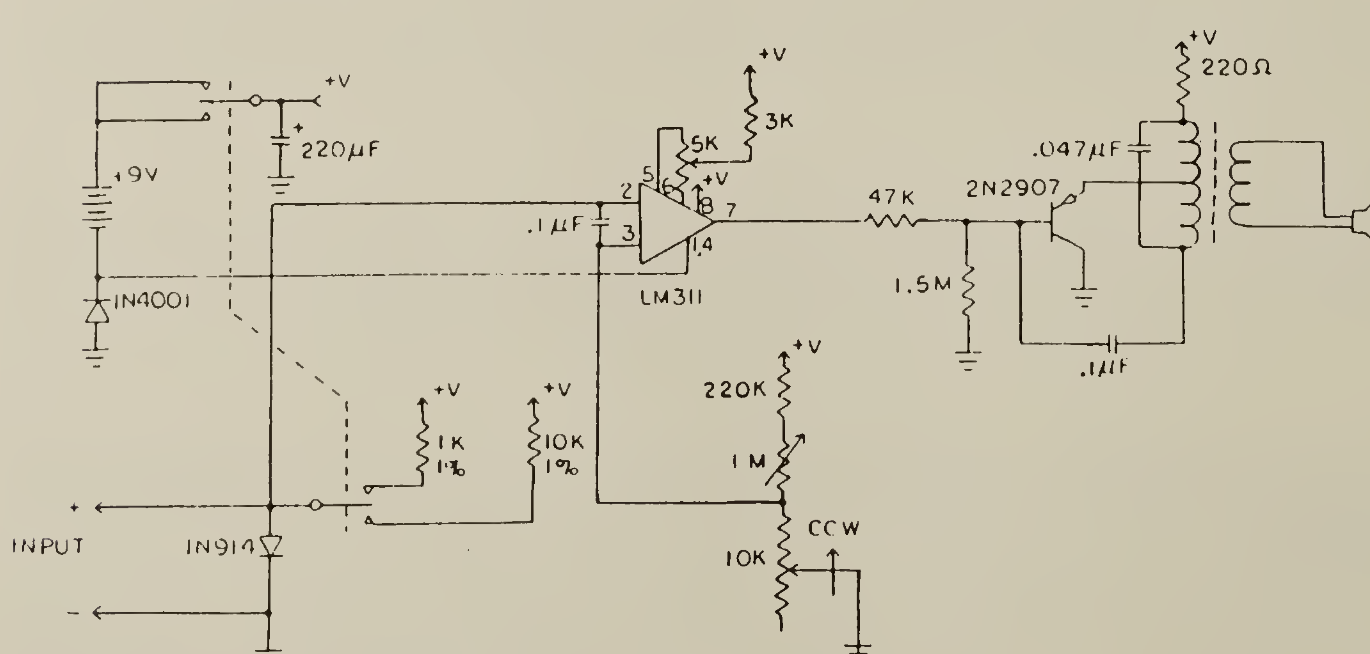


Figure 8. Low-Resistance Ohmmeter Circuit

e. Auditory Breakout Box

We have made several improvements to the Smith-Kettlewell Auditory Breakout Box (see *1986 Annual Report of Progress*), and have completed its transfer to production this year.

We investigated a number of alternatives for the jacks used on the box and selected an inexpensive eyelet. In addition to the low cost, the eyelets can be soldered directly to a printed circuit board. To this end, we designed a PC board to hold the eyelets and to function as the cover of the box. Also, a second PC board was designed for the circuitry of the box. *Figure 9* is a picture of the redesigned Breakout Box, which is now commercially available through our Rehabilitation Engineering Service. Plans are also in train to distribute it in England through the Royal National Institute for the Blind.

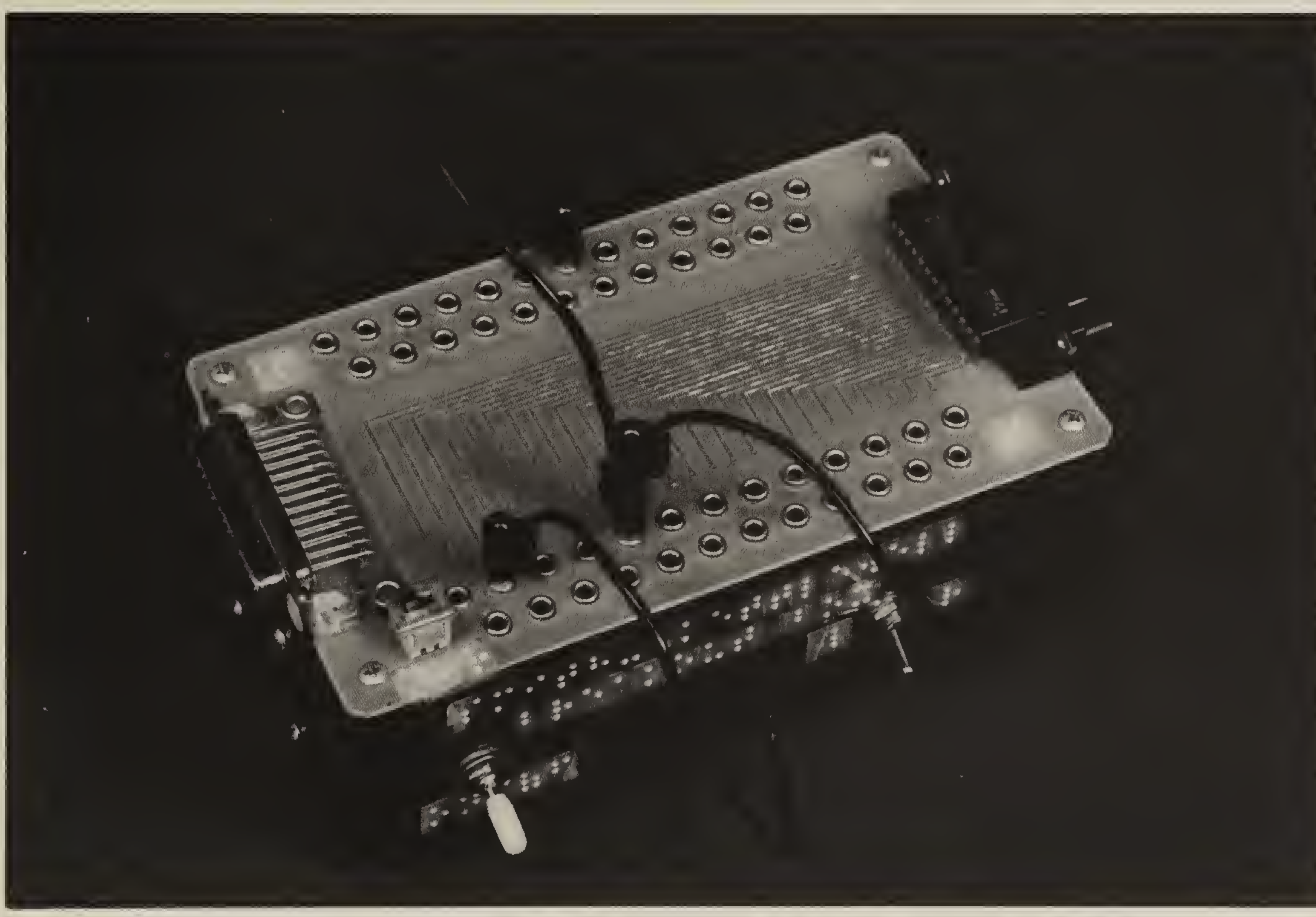


Figure 9. Auditory Breakout Box (Production Version)

B. EDUCATIONAL AIDS

1. FLEXI-FORMBOARD

Adaptive Communications Systems, Inc. has incorporated the following design modifications into the Smith-Kettlewell-designed Flexi-Formboard this year: (1) the underside of each shape template is now covered over to allow for a blank space on the board's surface. This provides a place for each template on the board at all times, thus preventing the loss of pieces which earlier had to be placed alongside the unit when not in use, and (2) decreasing the height of the templates to make them more of an integral part of the board's surface. ACS anticipates actual production of the Flexi-Formboard before the end of this calendar year.

2. TACT TELL MAP

During the past grant year, Martin S. Michael, San Jose State University student, completed the Tact Tell Map to a degree which allowed it to serve as his Master's thesis project. This required making modifications to the system which he had fabricated the previous year in response to both alpha and beta test site evaluations. All alpha site evaluators were adults, and their comments resulted in software modifications to (1) increase the time allotted for the user to remove all the pieces from the puzzle prior to the start of the game; (2) reduce the system's response time once a puzzle piece was inserted; (3) improve the synchronization of the information expressed by the speech synthesizer with the computer's monitoring of the status of the puzzle; (4) vary the congratulatory remarks of the positive feedback to make them more interesting; (5) present advanced skill level games in sequence (*i.e.*, none should be skipped, even though a perfect score was achieved on a lower level); (6) have the word *test* changed to *game*; (7) recycle missed questions; (8) allow a maximum of 30 seconds for a response from the user at the easiest level; (9) replace the statement "You have had enough time" with a restatement of the question; (10) have the speech synthesizer incorporate the user's name into the questions; (11) have all the words shown on the computer monitor spelled correctly, even though spelling variants are needed for correct pronunciation by the speech synthesizer for some of the words (this improvement was only partially completed); (12) have the speech synthesizer enunciate all statements shown on the monitor; and (13) improve the pronunciation of some of the words through the speech synthesizer.

Mr. Michael described the results of the beta site testing in his Master's thesis:

> These tests were conducted at the School for the Blind in Fremont, California. The students involved were blind or had low vision, but had normal motor skills. They were at a third grade, sixth grade, and high school level. The evaluation was conducted in a few sessions over the period of a week. There was some difficulty in setting up the system with the Apple IIe computers at the school, and I had to personally assist them. This delay at the beta site is mentioned because, as is the case with most beta site results, these required about twice as much time to get as had been allocated.
>
> The problems with the set-up procedure resulted in [a new] installation procedure . . . . All other beta site results are listed below:
>
> 1. Training was required with the younger children to teach them the basic geography they needed to know in order to answer most of the questions. This was expected as the teaching system serves primarily to reinforce lecture material;

2. The instructor started explaining the puzzle operation by showing the children the orientation of the pieces and explaining what the pieces are. Most pieces were remembered by any tactile particularities they had (i.e. the Florida panhandle on the U.S. piece, "South America is shaped like an ice cream cone," etc.);

3. Once the piece's orientation was learned the instructor placed Dymo labels on each piece with a letter to distinguish colors for the blind children;

4. The children were trained during the initial games by the instructor giving verbal clues;

5. The children caught on quickly and liked playing the game;

6. The pieces were too complicated for the children to fit them easily into the puzzle, especially Greenland;

7. Central America is a relatively small piece;

8. For low vision children the puzzle piece background should be a different color than the oceans;

9. Success with the questions varied with the understanding of world geography (i.e., the third grader could only do the level two questions);

10. The general format of the game and its execution were fine;

11. The quality of the speech from the DECtalk was appreciated, because the students were used to hearing the Echo GP speech synthesizer;

12. Since some of the students at the school are studying specific geographic areas (i.e., the original thirteen colonies) it would be nice to apply this technology to other puzzle maps. (Comment: this could be easily done given the time and the maps, but probably the more general-purpose approach to the interface hardware should be designed.)

The Tact Tell Map is now back in the Smith-Kettlewell laboratories. Within the past month we have made one hardware modification and several software modifications. The hardware modification was done in response to difficulties experienced by low vision individuals in seeing where to place the puzzle pieces on the map. This was easily remedied by repainting these surfaces a flat light gray to provide contrast against the shiny blue of the surrounding oceans.

Included in the new software improvements are (1) faster boot-up procedure, (2) improved pronunciation through an Echo Speech Synthesizer, (3) virtually instantaneous feedback in response to the user's answers, (4) positive feedback on the screen is backed by a flashing window, (5) music is played during the time the user is to remove all pieces prior to beginning the game, (6) music is played as part of the positive feedback at the end of the game, and (7) the beginning of an authoring system has been added.

This last feature adds flexibility to the system which is vital to its use in the classroom. It will allow the teacher to have the system pose *any* question s/he wants at any time, as long as the puzzle pieces answer them. For example, questions which have the "United States" as their answer could vary from "Insert the country whose capital is Washington, D.C.," to "Find the country where baseball is the national pastime."

An overview of the Tact Tell Map's value to the young user is nicely expressed by Mr. Michael in his thesis:

> . . . a large variety of concepts can be learned from this system, some of which are listed below:
>
> 1. Many geographic, cultural, and demographic concepts about the six areas represented by pieces in this puzzle can challenge the student. For example, questions from the system already range from: "find the country where French is the official language" to "find the country in which the New York Yankees reside." Anyone who knows BASIC can alter the questions asked by the system;
>
> 2. The student can learn relative locations of the geographic areas and their shapes;
>
> 3. Sighted children can learn basic colors, since there are five of them used on the pieces;
>
> 4. They can learn the concept of puzzles and how to work with them;
>
> 5. Students can learn the fundamental operator skills needed to start a small computer;
>
> 6. The first experience with a teaching machine is made more enjoyable because the lessons are given in a game format. The system can develop fundamental skills needed to work with a teaching machine, such as the following specific directions in the given amount of time.

These can be valuable lessons for a young child, sighted or blind. The teaching system can naturally incorporate these skills in a child's repertoire through playing a game with the computer.

If a human instructor is also available while the student is playing the game, there is plenty of time for student/instructor interaction at the lower levels of play. The instructor can know the possible questions in any sequence and use the teaching machine to reinforce concepts or facts already presented in class. The instructor may also want to teach very young children how to use the puzzle without the computer driving it. This can improve their dexterity and give them concrete examples of what a geographic area is.

C. RESEARCH FOR THE MULTIHANDICAPPED

1. DEXTER: A MECHANICAL FINGERSPELLING HAND FOR DEAF-BLIND USERS

During the first half of the past grant year, Dr. Deborah Gilden of our staff and Ms. Lindsay Gimble, Certified Interpreter, analyzed the accuracy of Dexter's hand configurations for the various letters of the one-hand manual alphabet. In addition, they initiated a determination of the sequence of individual finger movements required to achieve smoother letter-pair transitions. Mr. David L. Jaffe of the Palo Alto VA Medical Center modified the software to incorporate these improvements.

Overlapping these activities was the design and fabrication of Dexter II (*Figure 10*) an improved mechanical fingerspelling hand. As with the original Dexter, this new hand was a class project conducted by graduate students at Stanford University's Department of Mechanical Engineering, although this time the financial support was provided by the VA rather than by Smith-Kettlewell. Smith-Kettlewell, however, served as the consultant to this project.

Dexter I was an impressive accomplishment. In a remarkably short period of time, a team of four students developed a functioning and usable fingerspelling hand.* This device is now the foundation for any improved systems in the future. Accordingly, Dexter II is a response to the evaluation of Dexter I. The following lists allow for easy comparison of the two Dexter systems:

Dexter I	Dexter II
Large hand	Hand the size of a 10-year-old girl's
Machined aluminum fingers and palm	Delrin fingers; sheet aluminum palm
Pneumatically driven with actuating equipment and valving housed in two separate assemblies	DC servomotor driven with driving circuit, etc., housed in one compact unit
Approximately 2 letters/sec	Approximately 4 letters/sec
Pauses in neutral position between letter pairs	Pauses to hold letter position; moves through neutral between pairs

These improved design modifications have resulted in a much lighter, more compact, more portable system which is extremely easy to run. The need for a constantly available supply of compressed gas tanks and the problems of freeze-up and leakage have been totally eliminated. In terms of the actual tactile fingerspelling process, Dexter II is more accurate, fluid and rapid in its letter presentation, thus making it a more intelligible communicator.

**Special acknowledgment for both Dexters goes to Mr. Jim Anderson, machinist at the Palo Alto VA, for his invaluable contributions. Thanks also go to Mr. Jim Kramer, graduate student at Stanford, for a tremendous amount of design input concerning Dexter II.*

Dexter II with keyboard and interface

Dexter II with glove

Figure 10. "Dexter" Fingerspelling Hand (Version II)

Dexter II has been shown to members of the deaf-blind community in the San Francisco Bay Area. Most users tried it either during a demonstration at a camp for deaf-blind people or at a local social deaf-blind club. Within brief exposure periods, it was demonstrated that Dexter could be read tactilely by those used to receiving tactile fingerspelling. For most users the system could present letters at a rate more rapid than the user could receive, except for one individual who is a very fast fingerspeller receiver. Thus, Dexter II's presentation rates appear adequate.

Dexter II is the personification of the team approach through the collaborative efforts of complementary organizations. Smith-Kettlewell, Stanford, and the VA have each fertilized this project with their respective unique areas of expertise.

2. TELEBRAILLE

The TeleBraille is a communications device for the deaf-blind. Early development of this system was conducted through the auspices of the Smith-Kettlewell REC. The resulting device has been manufactured by Telesensory Systems, Inc. (TSI) for several years and is based upon a commercial Telecommunications Device for the Deaf ("TDD"). This commercial unit has gone out of production, necessitating the design of an updated system. The TeleBraille was the only device available in this country which allowed the deaf-blind to communicate with other people through the phone lines. As many states now have programs which supply TDDs for deaf and deaf-blind users, there is a significant need for a replacement TeleBraille; TSI feels, however, that the relatively small number of deaf-blind users does not justify a commercially funded development project.

Consequently, our REC was approached by TSI with a view to collaboration in the design of a modernized system. We are undertaking the research and development work for the system, and should the project be successful, it will be put into production by TSI.

We have been canvassing the needs and desires of the deaf-blind community to determine the features and improvements which need to be incorporated in any new device. The original unit includes a "face-to-face" mode for direct interpersonal conversation. There is general agreement that this, along with other features, should be incorporated into our new design.

We have also begun a study of existing TDD technologies, and have enlisted the cooperation of Mr. Ralph Krongold of Krown Research, Inc., a prominent manufacturer of TDDs. Mr. Krongold has proven extremely helpful, and we have been able to evaluate a special modem, manufactured by his company, which could well be incorporated as the heart of a new TeleBraille. However, contacts are also being made with other makers of TDDs to determine the applicability of their products and their interest in assisting us in this project.

For the software development needed for the implementation of the TeleBraille control structure, Archimedes Software of San Francisco has kindly agreed to allow us to use a copy of their SIMCASE system without charge for the term of the project. As this system is valued at $2000, this cooperation from Archimedes (as well as their promise to provide documentation on floppy disk) is very much appreciated.

Through our contacts with Dr. John Gill of the Royal National Institute for the Blind in England and Dr. Jan-Ingvar Lindstrom of the Swedish Handikappinstitutet, we are also exploring the possibility of making a version of our design compatible with the codes and voltage levels used in Europe, in order to make a telecommunications device for the deaf-blind available there also (there is currently no such system in Europe).

3. THE DOTLESS BRAILLE READING MACHINE

The Dotless Braille Reading Machine has been used for testing purposes by three blind and three deaf-blind subjects. In contrast with the intended population, none of these individuals suffers from lack of fingertip sensitivity. All of the subjects were presented with individual letters. In addition, the deaf-blind subjects were asked to "read" a short phrase in Grade I Braille, and two of the blind subjects were presented with portions of cohesive texts in both Grade I and Grade II Braille. The text consisted of brief humorous stories - ideal materials to test comprehension.

All of the subjects were able to use Dotless Braille to read the materials presented to them with near-perfect accuracy, but the process of being able to do so was exceedingly slow and laborious. The impact of this on comprehension was beautifully demonstrated by the reactions of the blind subjects who received the running text. Their reception was fragmented, reduced to a series of letters which they had to consciously synthesize to form words, which then had to be put together to form sentences, which then had to be put together to form the story. This process was evident to the researcher from their comments during the reading process, followed by the delay at the end of the process as they "reworked" and synthesized the information, followed finally by their delayed laughter in response to the humor in what they just "read"!

Practice sessions by the blind subjects indicated that although it is possible to increase reading speed with this device, the learning curve is not at all steep. The results also suggested that it would be wise for the user to master Grade I Braille on the Dotless Braille Reader before embarking on Grade II.

If we eventually learn that this system continues to be a slow way of receiving information even after a great deal of practice, this does not negate its importance as a tool for individuals in the intended target population. For those with neither vision nor hearing, who relied on braille for all receptive communication and then lost even this sensory channel, Dotless Braille would provide the only means of receptive communication available to them.

4. USHER'S SYNDROME STUDIES

This year, Dr. Lea Hyvarinen, world-renowned ophthalmologist in the field of low vision as well as deaf-blindness, joined our staff for a 6-month study of vision assessment methods in the deaf-blind population. The study was completed on schedule.

The study had two principal goals. The first was to study, and thereby recommend, better techniques for the communication process among the eye specialist, the deaf-blind patient, and the interpreter during the eye examination. The second was to better characterize the functional visual deficits in this population, especially those associated with Usher's Syndrome, and to devise improved tests to measure these deficits. This would allow rehabilitative measures to be based on a sounder knowledge of the actual visual impairments. In both of these areas the project was successful.

Dr. Hyvarinen was assisted throughout the project by Lindsay Gimble, who acted as both interpreter and research assistant. One of the major tasks was in patient recruitment and scheduling, in which we were assisted by the cooperation of the Helen Keller National Center and the Oakland Lions Blind Center. Financial assistance was also received from Boy's Town, Omaha, Nebraska, and offers of assistance with publication costs for the resulting training manuals have been received from other outside sources.

During the course of the study, over 30 patients with various degrees of visual and auditory impairment were examined by Dr. Hyvarinen, with Ms. Gimble as interpreter. The examining sessions were all videotaped for subsequent analysis. The examinations were considerably more exhaustive than standard clinical practice, and included (in addition to all the standard tests of acuity, field, etc.) tests of low-contrast acuity, flicker sensitivity, vestibulo-ocular function, and glare recovery, among others. Many of the latter tests were developed in the laboratories of the REC and other investigators at Smith-Kettlewell. In each session, a full case history was taken, including details of mobility skills. Comfortable illumination levels and communication field and distance were established, followed by the battery of vision tests. The following is a sample of the tests used:

Traditional clinical tests included:

- Visual acuity (distance and near)
- Smallest text read (m-scaled)
- Goldman field test
- D-15 color test, Adams desaturated
- Accommodation test
- Retinoscopy

Non-traditional tests included:

- LH5 contrast sensitivity test
- Cambridge low-contrast gratings
- Flicker sensitivity
- Glare recovery
- Balance test
- Effects of yellow filters

Tests used on only a sampling of the patients included:

- Hearing tests
- Lip-reading tests
- Flicker fusion at different luminances
- Spectral sensitivity

The result was a more comprehensive body of vision test data than has hitherto existed on this population, and which will enable a better understanding of the course and nature of the complex vision impairments which result from these diseases. These data are still being collated and analyzed for publication. Another result was the identification of the most appropriate tests for future clinicians to use with these patients - including certain tests which may facilitate discrimination among the different types of Usher's syndrome (hitherto a very difficult task).

In the realm of improving communication methods, the taped exam sessions were edited and synthesized into a training videotape for interpreters, while training manuals for interpreters and patients were written. Now in preparation are summaries of this material in a form suitable for the education of clinicians in the optimal techniques of communication during the examination of the deaf-blind patient to ensure accuracy of the resulting clinical data.

A full report of the study will be made next year when the current data analyses and training manual preparation are complete and published.

5. VESTIBULO-OCULAR REFLEX STUDIES

a. Adaptation Problems in the Vestibulo-Ocular Reflex

The ability to increase or decrease vestibulo-ocular reflex (VOR) gain is essential to the goal of rehabilitating persons with VOR disorders, the symptoms of which include dizziness, nausea, and oscillopsia. In previous experiments, adaptive gain decreases were activated comfortably and rapidly. During the last year experiments were run to determine whether adaptive increases in VOR gain could be activated comfortably and rapidly.

In six subjects, adaptive gain increases were not conclusively activated. The visual environment constructed for this experiment, namely the target and background arrangement, were not an effective adaptation stimulus. It is hypothesized that the stimulus was too close to the subjects, and also that it did not fill enough of their visual field.

Additional experiments are needed to find the stimulus that can activate VOR gain increases, and then formulate an effective paradigm for reducing symptoms produced by VOR disorders.

b. VOR In Usher's Syndrome

People with Usher's Syndrome exhibit balance deficits and perform below normal on vestibular tests. The severity of the deficits has been linked to a particular type of Usher's Syndrome. The goal of these experiments was to characterize the vestibular deficits in these patients, and develop a database correlating the deficits associated with the various types of Usher's Syndrome.

During the past year we measured the vestibulo-ocular reflex in a group of Usher's patients. These tests are often used to diagnose similar problems in non-Usher's patients. Results from 11 patients fell into three categories. The majority of patients (7) showed severe VOR deficits. Their VOR gain was very low, and delayed in time. A second group of patients (3) showed normal responses to high frequency rotations, but severe deficits at low frequencies. One subject had completely normal responses.

These results are being correlated with the results of a battery of visual and auditory tests to better describe the numerous Usher's Syndrome types (see Usher's Syndrome Studies, Section 4 above). The accumulating database will improve physicians' ability to formulate treatment and remediation plans, and to make more accurate prognoses.

D. ORIENTATION AND MOBILITY RESEARCH

We have extended our basic studies of mobility this year. The goal is to characterize the information needed for mobility, so that future generations of electronic travel aids for the blind can be based on a sounder understanding of the problem.

1. STUDY OF MOVING SUBJECTS

A "Study of Mobile Subjects" was completed, in which five experienced and skilled blind travelers were asked to follow a 12-block route leading through both familiar and unfamiliar areas, and encompassing both an urban shopping area and a residential neighborhood. Subjects were asked by the experimenters to report all information they perceived and used for guiding their travel, and also to describe how each piece of information was perceived or derived. This information was recorded on tape as a running commentary as the subject moved along the route. Remarks of the experimenters were also recorded, and consisted mainly of directions to the subject and interrogation to clarify the subjects' remarks. After each trial, the subjects were debriefed in a recorded interview session in which they were asked to identify any additional information they would like (in an "ideal world," without consideration of what might be available or of expense) to receive during travel.

The commentaries were transcribed and scored using a scoring system devised by Dr. Emerson Foulke, our collaborator on this project. A sample of the scored commentary from one subject ("C") appears in *Table I* (next page), while the Appendix (page 42) contains a longer excerpt, followed by the resulting scoring annotations and an explanation of the scoring system.

To give an idea of the types of analyses which this approach allows, an example of data from another subject ("G") is shown in *Table II* (next page), broken down into perceived facts, remembered facts, and inferred facts. It can be readily seen, for example, that the latter two categories are much more numerous on the familiar part of the route than on the unfamiliar. Many alternative analyses can be used to yield objective data on many aspects of cues used during travel, with particular emphasis on the *source* of each piece of information enunciated by the subject - whether via hearing, touch, memory, deduction, etc. The volume of resulting data was considerable, and the full analysis is still under way.

We believe this study represents the first systematic analysis of what information skilled blind travelers actually use for orientation and mobility. This gives a firm idea of what information would be redundant in a travel aid, and what is achievable as a maximum level of performance of mobility with a long cane only. It will serve as a baseline for the development of travel aids and mobility training programs. The results will be fully collated and published in professional journals to ensure their availability to other researchers and mobility aid developers.

2. INTERSECTION CROSSING EXPERIMENT

One of the features arising from the above study was the surprising tendency of even experienced blind travelers to make mistakes regarding the type and operation of intersection controls and to make occasional unsafe crossings - *e.g.*, crossing on a red light and/or when cars were approaching. In our debriefing of the subjects, a frequent comment was that more information about the nature and status of intersections would be a most helpful piece of additional infor-

TABLE I. SAMPLE OF SCORED COMMENTARY

In the protocol that follows, the subject and the experimenters are identified by the initial letters of their last names. The protocol also includes statements labeled as comments that have been added to clarify statements made by the subject or to indicate the need for clarification, to draw the reader's attention to the significance of statements made by the subject, and to explain scoring decisions.

The route on which subjects were observed went south from the front door of Smith-Kettlewell to the corner of Webster and Clay, west along the north side of Clay to Fillmore, south along the east side of Fillmore to Bush, east along the north side of Bush to Buchanan, north along the west side of Buchanan to Clay, and west through the hospital grounds on the closed segment of Clay to Webster. All subjects were familiar with the segment of the route from Smith-Kettlewell to the corner of Fillmore and Bush, and all of the subjects had little or no familiarity with the segment of the route from the corner of Fillmore and Bush back to Smith-Kettlewell.

Subject: "C" Experimenters: John Brabyn and Emerson Foulke Date: November 1987

C: We go out here and I'm going to look for this echoey garage, and I hit this wall here. 1m(sa)p(a.ve) 2p(c)

B: You veered to the left into the garage.

Comment: C's memory of the garage is probably evoked, not by an environmental cue, but by as associative cue. He verifies his expectation by listening for the echo. Because he veers as he passes the entrance to the garage, he hits the garage wall with his cane.

C: And now we've got the wall, so I'll go up here and hit this crossing here. 3p(a) 4m(s)p(a.ve)p(c.ve.ca) 5m(dr)

Comment: C is referring to the garage wall that is parallel to the sidewalk and on his left. He maintains his position on the sidewalk by monitoring the sound reflected from the garage wall. He remembers this situation and expects the garage wall to come to an end shortly. He verifies this expectation by listening and by finding the end of the wall with his cane.

TABLE II. SAMPLE OF DATA ANALYSIS

Perceived Facts

	fam	unf	ttl
#4[p(a)]	12	18	30
#9[p(acva)]	1	0	1
#10[p(c)]	4	6	10
#16[p(f)]	1	4	5
#23[p(k)]	1	0	1
#24[p(c)p(hvc)]	1	0	1
#30[p(o)]	0	1	1
#32[p(d)]	2	3	5
Totals	22	32	54

Remembered Facts

	fam	unf	ttl
#1[m(s)p(ave)]	1	0	1
#2[m(dr)]	1	0	1
#3[m(s)p(fve)]	1	0	1
#7[m(s)p(cve)]	2	0	2
#8[m(s)p(fcve)]	1	0	1
#11[m(sa)]	7	2	9
#12[p(ar)m(s)]	2	0	2
#13[m(sa)p(cve)]	1	0	1
#14[m(sa)p(ove)]	1	0	1
#17[m(sa)p(fve)]	2	0	2
#21[p(ar)m(s)p(cve)]	1	0	1
#22[m(s)p(kve)]	1	0	1
#25[p(or)m(s)]	1	0	1
Totals	22	2	24

Inferred Facts

	fam	unf	ttl
#5{i[p(f)m(sa)]}	1	0	1
#15{i[m(sa)p(a)]}	3	0	3
#18{i[m(sa)p(a)p(a)]}	1	0	1
#19{i[p(ar)m(g)m(s)]}	2	0	2
#20{i[m(s)p(a)]}	1	1	2
#26{i[p(f)m(g)m(g)]}	0	1	1
#27{i[m(g)p(a)p(cve)]}	0	1	1
#28{i[p(f)p(a)]}	0	1	1
#29{i[p(a)m(g)]}	0	3	3
#31{i[p(a)p(a)]}	0	2	2
#33{i[p(a)m(a)m(g)]}	0	1	1
#34{i[p(a)m(sa)m(sa)]}	0	1	1
#35{i[p(a)p(a)m(ag)]}	0	1	1
#36{i[p(ave)m(ag)]}	0	1	1
Totals	8	13	21

mation which might be included in future travel aid outputs. Certainly, the amount of time spent by the subjects waiting at intersections (especially the relatively quiet and unfamiliar ones) appeared to be large.

As a pilot study to examine this problem further, we asked three experienced blind travelers to cross certain intersections repeatedly, while the researcher timed the delay between the lights turning green and the subjects' beginning the actual crossing. We also noted any unsafe crossings. In our first pilot study the average delay was 10 seconds, but varied widely from 2 to 65 seconds. Three unsafe crossings were recorded. We are considering more detailed studies of this problem.

3. SIMULATION STUDIES OF A NEW NAVIGATION DEVICE FOR THE BLIND

Our strategy for the design of new travel aids involves simulation, to avoid having to build expensive hardware and to maintain greater flexibility. Our method is to simulate the aid by having an experimenter present the desired information (manually, auditorily, etc.) to the blind subject as he travels. We have implemented this approach in a feasibility study for a new type of travel aid being developed in collaboration with Ron Milner of Applied Design Concepts Inc., Grass Valley, California. This research dovetails with our basic mobility studies outlined above, which have already provided clues as to the types of information it is desirable to present.

Electronic travel aids for the blind traveler have historically focused on obstacle location and/or avoidance. The first commercially available device to provide navigational information through identification of objects in the environment was the Talking Signs developed at our REC. This system has transmitters which can be pre-programmed to contain up to a 3-second message to be retrieved by the blind traveler through synthetic speech by activating a hand-held receiver. Talking signs requires installation of transmitters at the site to be identified, *e.g.* a building entrance or an intersection name sign.

The "Navigator" is a proposed device which will be worn by the traveler and require no installed transmitters. Sensors will monitor direction and distance traveled, and an internal microprocessor will use this information to calculate the user's position along a pre-recorded route. Verbal human descriptions of relevant environmental features, pre-recorded by a sighted traveler traveling the same route at an earlier time, will be available upon request (by pressing a button) at any point along the route, as will certain other information such as direction of travel and distance to and from the nearest intersections. Spontaneous announcements from the device will accompany any deviation from the route and any dangerous veering at intersections. Tones will sound automatically at important points such as intersections, to suggest good times for the user to request more detailed information about the route.

We have begun simulation of this system using a dummy device (*Figure 11*) carried by the subject. The device incorporates four pushbutton switches connected to a beeper. The subject can interrogate the simulated "navigation aid" (the researcher) by pressing the buttons to request different types of information. The experimenter can tell which button (No. 1 to No. 4) was pushed. If the subject pushes, for example, number 1, the experimenter knows he is to tell the subject how far it is to the next intersection; if number 4 is activated, the experimenter knows he is to give a running description of all the relevant features of the nearby environment, as outlined above.

The study is now under way with external funding from Applied Design Labs, which, with support from us as subcontractors, received an NIH Small Business award to study the feasibility of the new device. Our approach will allow the validity of the new device to be proven or disproven without spending several years and large amounts of research and development money in the building of complex hardware.

Figure 11. "Navigator" Simulation Unit

E. PEDIATRIC VISION SCREENING RESEARCH

We have completed a field study of the accuracy of our Polaroid photorefraction device, described in our *1987 Annual Report of Progress*. In this study the adapted camera was tested for an extended period in a pediatric clinic and in our own pediatric laboratory. Results of Polaroid photorefraction of 85 infants were compared to the refraction obtained by a pediatric ophthalmologist using retinoscopy under cycloplegia. This study indicated that the camera is sufficiently sensitive to be used as a mass screening device (*Figure 12*). It has allowed detection of previously overlooked potentially blinding impairments in a number of cases. The results were reported at the annual meetings of the Association for Research in Vision and Ophthalmology and the Association for Pediatric Ophthalmology and Strabismus. A paper summarizing the findings is in press for the *Journal of Pediatric Ophthalmology and Strabismus.*

Another achievement during the past year was the completion of an optical analysis of image formation in photorefraction. This was accomplished in collaboration with Wolfgang Wesemann, Ph.D., who has now returned to the University of Hamburg after a year and a half of work in our pediatric lab. The analysis is now in press in the *Journal of the Optical Society of America.* Through this analysis, and our practical experience with the Polaroid device, we have determined the necessary parameters for accurate calibration of the camera and for achieving the desired sensitivity for screening.

The analysis also suggested that the design tolerances of photorefractors and the scoring of photographs is sufficiently critical to preclude a simple "universal camera attachment" (to fit any camera) which would be sensitive enough to be truly useful. We have therefore suspended activity on that aspect of the project, to concentrate on the refinement of the successful Polaroid version. We envisage the principal application of our device to be in pediatric clinics where early vision screening is presently rudimentary at best. Our new device will offer the potential, at very modest cost, for every pediatrician to conduct effective early detection of potentially blinding vision impairments as a part of his routine well-baby checkups. Considerable potential also exists for use in areas of the country (and the world) where vision specialists are seldom available.

(Hy ≥ 3.5, An ≥ 1.5, Cyl ≥ 2.5)

	Rx +	Rx -	
Pol + (≥ 1.25)	HITS (a) 15 (18%)	FALSE ALARMS (c) 18 (22%)	+PRED VAL a/(a+c) 45%
Pol -	MISSES (b) 3 (4%)	CORR REJECTIONS (d) 47 (57%)	-PRED VAL d/(b+d) 94%
	SENSITIVITY a/(a+b) **83%**	SPECIFICITY d/(c+d) **72%**	PREVALENCE (a+b)/(a+b+c+d) **22%**

Figure 12. Sensitivity and Specificity of Polaroid Photorefractor

Clinical criteria for significant refractive errors where any hyperopia >3.5 diopters, or any anisometropia >1.5 diopters, or any astigmatism >2.5 diopters. The median age of the 85 infants refracted was 6 months.

F. LOW VISION

1. NEW LIGHTING SYSTEMS FOR LOW VISION

In the field of illumination aids for low vision, we have completed and tested two new types of battery-powered illuminators, and work is well in hand on a third.

a. Battery-Powered, Multipurpose Lighting System

In collaboration with Alan Lewis, O.D., Ph.D., we have designed, built, and tested a head-mounted, battery-powered, low-voltage, high-intensity supplementary lighting system (*Figure 13*) for use in reading and other near tasks - suitable for both low vision and more general (*e.g.*, surgical) applications. The beam size is calculated to illuminate a page-sized area at normal reading distances.

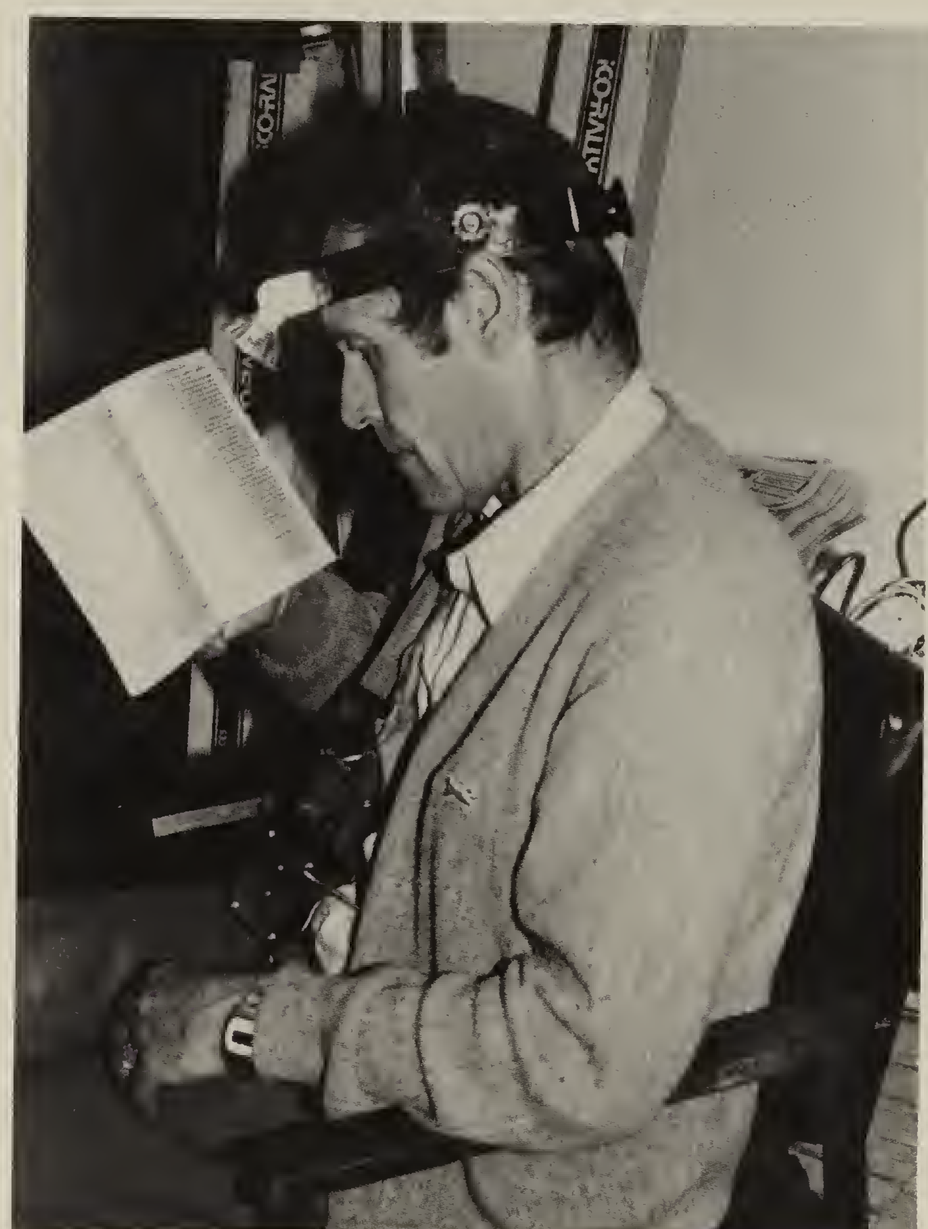


Figure 13.
Battery-Powered, Head-Mounted Low Vision Reading Light

The new prototype incorporates the quartz-halogen MR16 technology, and employs a precision dichroic reflector which utilizes dichroic coatings to alleviate much of the infrared problem common with conventional incandescent sources. The compact, lightweight, and efficient system is suitable for mounting on a head frame or band, spectacle, loupe, or hand magni-

fier to provide high-intensity localized illuminance, while the precision optics give excellent beam control and therefore minimize glare to others.

The prototype system uses a 20-watt bulb powered by a 12-volt, 5 ampere-hour nickel-cadmium rechargeable battery pack worn on the shoulder or belt. Full- and half-power switching is incorporated, and the batteries give approximately 3 hours of use at full intensity.

The unit has been tested and demonstrated extensively, including its application in surgery (using an optional add-on glass filter/protector in front of the bulb to filter out UV rays and avoid any danger due to glass splinters if the bulb shatters). All evaluators to date have been impressed with the intensity and quality of the resulting light, as well as the convenience of the head-mounted unit. The device was also demonstrated at the American Academy of Optometry meeting by Dr. Lewis, and received an enthusiastic reception.

We have conducted careful laboratory tests and measurements on the prototype, including a comparison test with a high-intensity, spectacle-mounted light used in ophthalmology. The light output of our system exceeded that of the comparison device by a factor of 20, providing two-and-one-half times the intensity and eight times the beam coverage, while using only twice the power. The luminance of typical reading material was measured at 1000 candelas per meter squared for normal reading distances - representing approximately 10 times that resulting from normal ambient room lighting. The unit thus provides a very useful increment in available light for the low vision user in reading and other near tasks. It is well known that such an increase in lighting level greatly improves the reading abilities and comfort of most low vision patients, and even that of elderly persons with normal vision.

In view of the wide range of potential applications, we believe the prospects for eventual commercialization are good. We are now in the process of exploring a number of improvements.

b. Spectacle-Clip Illuminator

A new project for this year has been the development of a spectacle-clip illuminator for the many low vision patients who read using high-powered (+20 to +40 diopter) spectacle lenses - resulting in a reading distance of approximately 1 to 2 inches. The problem faced by this population is that when the reading material is held up to the eye, the head partially or largely blocks any ambient illumination, making reading difficult. Our solution to this problem uses a small 1- to 2-watt light bulb and reflector which clip onto the user's spectacles in such a way that illumination is projected on objects held within a few inches of the spectacle lens used for reading (*Figure 14*).

Our calculations, applying the inverse square law, indicated that a 1-watt light source used at a 2-inch working distance would cast approximately the same light intensity on the reading material as a 60-watt reading light used at a standard working distance of 16 inches. Accordingly, we have constructed several prototypes using bulbs in the range of 1 to 2 watts, with reflectors and spectacle clips of various designs. In each case, operating power is derived from a small alkaline or lithium battery cell carried in the user's pocket or purse. When not in use, the illuminator can be easily unclipped and pocketed. Easily pocketed battery sizes give a working light of 2 to 3 hours.

Our most satisfactory prototype to date (*Figure 14*) uses a small cylindrical reflector in which are mounted two miniature krypton bulbs consuming approximately 1.8 watts. Initial testing has confirmed our predictions regarding the required light intensity, and the device produces a dramatic improvement in brightness of reading material in all indoor conditions. The prototype is now suitable for user field testing. However, considerable further development is

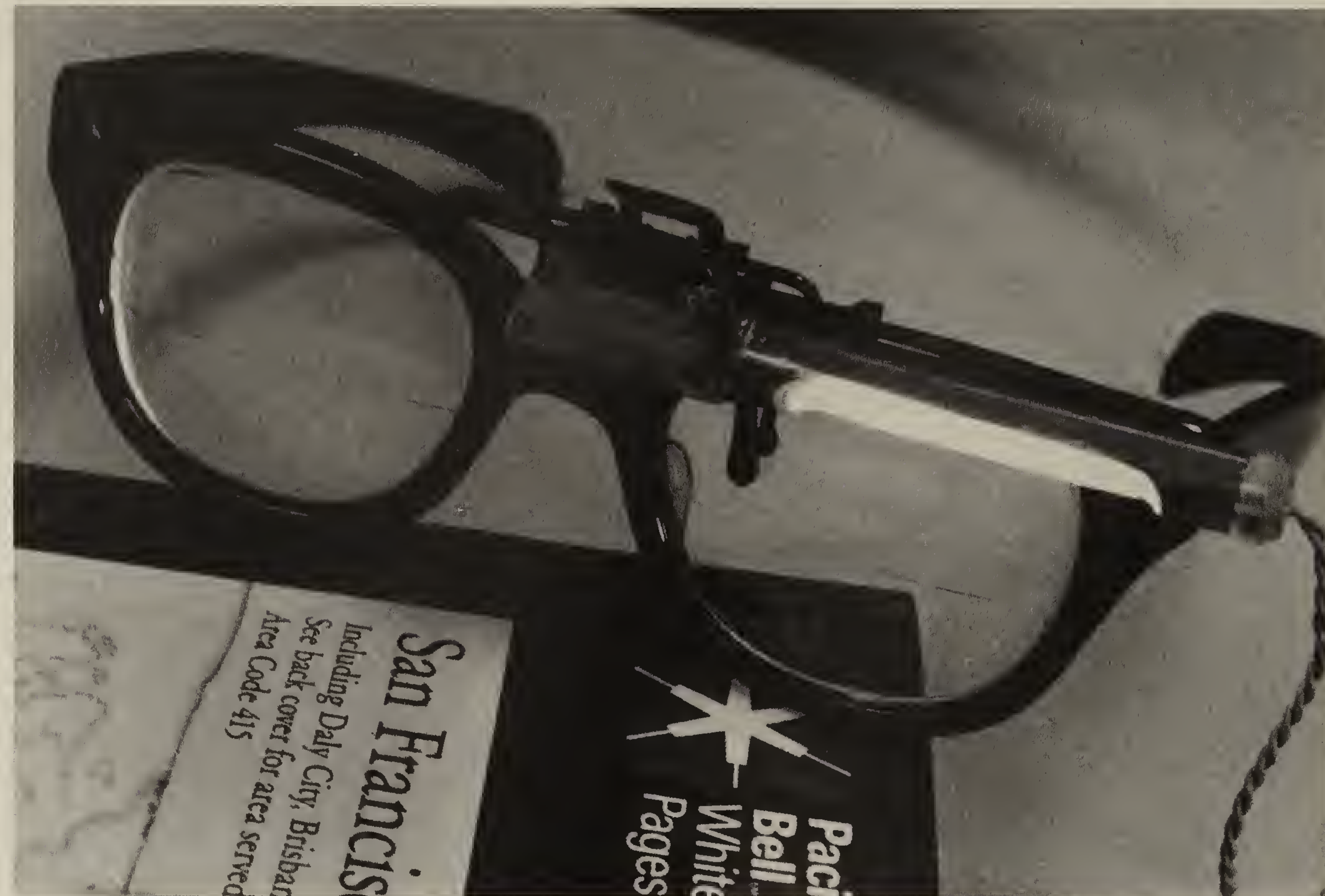


Figure 14. Spectacle-Clip Illuminator

needed to optimize the design in terms of cosmetic acceptability, ease of clip placement and removal, battery and bulb selection, etc. The options for producing an entirely spectacle-mounted unit (including batteries) are also being considered.

Development work on this project was started in December 1987; the work is now continuing under funding from the NIDRR low vision grant recently awarded to our REC.

c. *Fiber-Optic Illuminator For Use With Hand-Held and Stand Magnifiers*

While battery-powered incandescent or fluorescent systems have been used in some hand-held and stand magnifiers to help boost light intensity on the subject matter, they often provide insufficient light for low vision persons with high illuminance requirements. To address this problem, our consultant, Dr. Alan Lewis, designed a high-intensity lighting system using a highly efficient 70-watt metal-halide source (>70 lumens/watt), fiber-optics to deliver the light to the magnifier, and a three-mirror optical system in combination with a Fresnel lens to distribute the light on the work surface.

A prototype three-mirror optical system has been constructed in our laboratories, and the other system components are now being added by Dr. Lewis, who is exploring two main possibilities for light sources. The first is the metal-halide version described above; the second, just becoming available, is a new type of high-pressure vapor lamp which produces white light. Both of these newly emerging technologies are capable of producing very high illuminances, with excellent color and freedom from glare. They produce a minimum of heat, and the nature of our design allows placement of the light (and heat) source remote from the user - thus eliminating the major safety hazard and annoyance of heat from incandescent lamps.

2. LOW-CONTRAST ACUITY CHARTS

a. *Introduction*

We are now in the evaluation stage of our project to develop an innovative low-contrast acuity chart for the rapid measurement of visual contrast sensitivity. Detection of low-contrast and low-luminance targets are important parameters in assessing the functional vision in those with low vision, and existing tests are inadequate. The new concept combines the measurement of low-contrast and low-luminance vision performance into an eye chart of proprietary design (*Figure 15*), allowing a single rapid test of the patient's visual performance under conditions of reduced contrast and luminance.

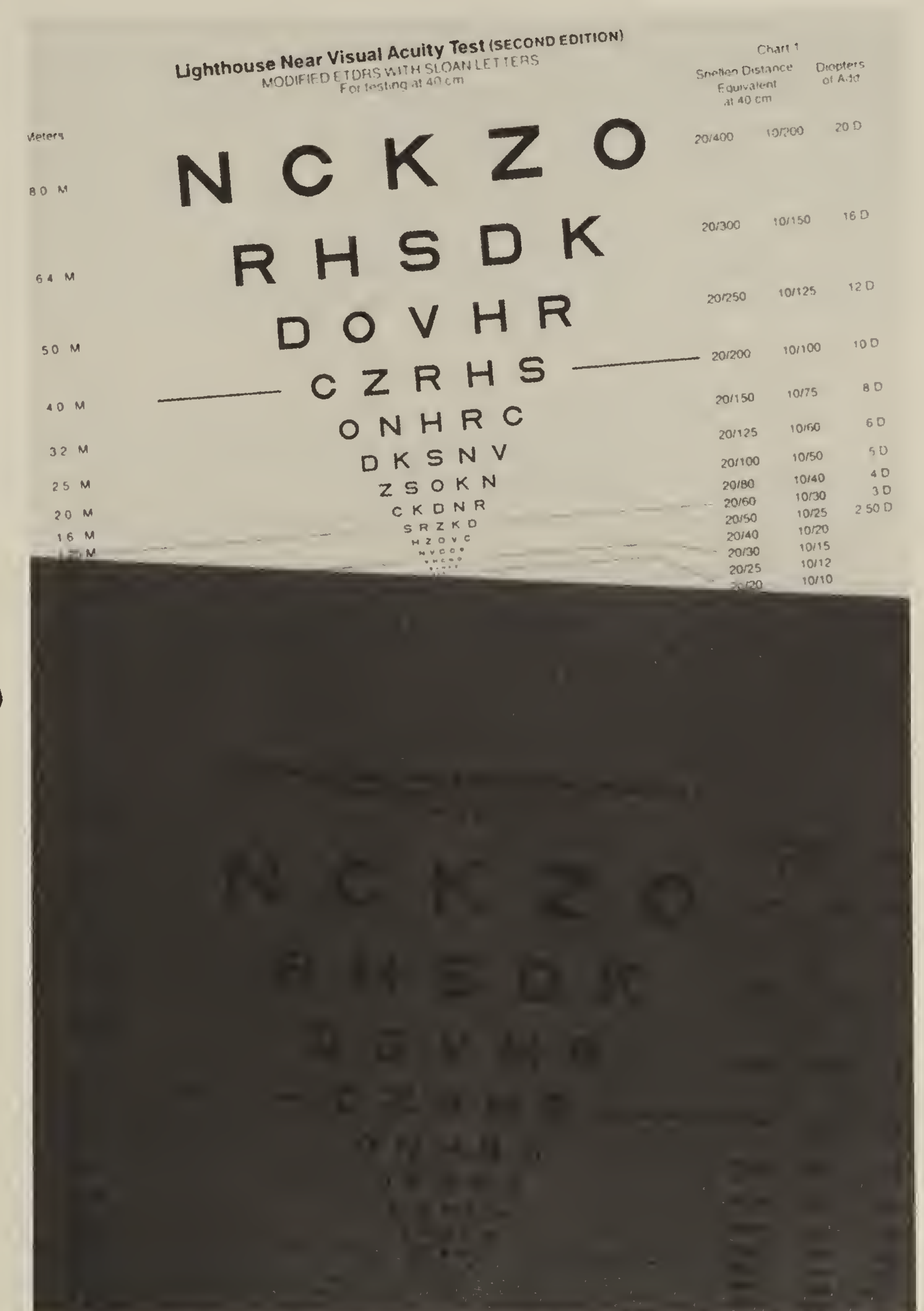


Figure 15
Low-Contrast, Low-Luminance Acuity Chart
(Comparison With High-Contrast Chart)

We have now produced both near and distance versions of this chart. The near version was developed this year using the just-available New York Lighthouse near vision chart as a starting point - in order to facilitate direct comparisons. We are indebted for the cooperation of Dr. Eleanor Faye of that organization for making early copies of the chart available to us for this

research. We reprinted the chart with black letters on a dark gray background, and calibrated the resulting contrasts in our laboratories using a photometer.

The new charts have been tested by Dr. Gunilla Haegerstrom-Portnoy in collaboration with the U.C. Berkeley Low Vision Clinic, using patients with early Age-Related Maculopathy (ARM) and an age-matched control group with normal vision. The methodology and results of this evaluation are described below.

b. *Methods*

Visual acuity was measured with best refraction in place including near add as needed. The measurements were made under normal room illumination (the luminance of the white background chart was x cd/m^2. Sixteen patients with very early age-related retinal changes participated. These patients showed macular drusen and changes in the retinal pigment epithelium, but still maintained good visual acuity. The average distance standard Snellen acuity for these patients was 20/25-1. The average age of the pre-ARM patients was 73 years (range 66-82 years). Another group of 11 older normals with good acuity and no or few retinal changes were also tested. They ranged in age from 53 to 79 years, with an average of 66 years. Their average acuity was 20/25+1. In addition, a group of nine young healthy normals were tested. Their average age was 25 (range 17-30 years) and their average Snellen acuity at distance was 20/20+1.

c. *Results*

The results are presented as differences between charts in units of log MAR. A difference of 0.1 is equivalent to a whole line on the standard Sloan chart. There are four comparisons:

(1) Distance Bailey-Lovie high-contrast chart (96% contrast) to distance Bailey-Lovie low-contrast chart (15.8% contrast); both of these charts have white backgrounds. The luminance of the background was about 50 cd/m^2.

Pre-ARM patients: Mean 0.22 log MAR (s.d. 0.10): indicates that on average the pre-ARM patients showed acuity values 2 lines lower on the low-contrast chart compared to the high-contrast chart.

Old normals: Mean 0.13 (s.d. 0.06): the acuity of older normals decreases about a line and a half when the contrast is reduced while the background luminance remains constant (and high).

Young normals: Mean 0.08 (s.d. 0.05): young normals only lose less than one line when contrast is reduced from 96 to 16%.

(2) Near standard Sloan high-contrast chart (93% contrast) compared to the same chart printed on darker paper (the paper is 0.85 log units darker than the standard chart, which has a white background); the contrast of this chart is 55%.

Pre-ARM patients: Mean 0.19 log MAR (s.d. 0.13): even though the contrast of the letters is much higher than in comparison #1, the loss of acuity is about the same - 2 lines on the chart.

Old normals: Mean 0.20 log MAR (s.d. 0.06): the older normals also showed a loss of 2 lines on this chart, a comparable loss to the pre-ARM patients.

Young normals: Mean 0.14 (s.d. 0.06): the young normals lose about a line and a half.

(3) Standard high-contrast near Sloan chart (93% contrast) to the same chart printed on even darker paper (luminance is 0.96 log units lower than the standard chart, and the contrast of the black letters is 54%).

> Pre-ARM patients: Mean 0.26 (s.d. 0.12): on this chart the average visual acuity was reduced almost 3 lines compared to the standard chart, even though the contrast of the letters is still higher than in the first comparison. Note also that the contrast of the charts in comparisons #2 and #3 are about the same; the background light level is decreased by only one-tenth of a log unit more than in comparison #2, but an additional whole line of acuity is lost.
>
> Old normals: Mean 0.26 (s.d. 0.07) log MAR: the older normals lost the equivalent of almost 3 lines - a comparable loss to the pre-ARM patients.
>
> Young normals: Mean 0.14 (s.d. 0.06) log unit: young normals only lost about one-half line on this chart, no change from comparison #2. This result is not surprising since the contrast of the two charts is the same, and young normal observers ought not to be sensitive to a small (0.1 log unit) reduction in luminance.

(4) Standard high-contrast near Sloan chart (93%) compared to the same chart printed on a very dark paper (this is the darkest chart; the luminance difference is 1.07 log units; the contrast of the letters is 15.5%).

> Pre-ARM patients: Mean 0.6 log MAR (s.d. 0.21): this indicates that the pre-ARM patients lost 6 lines of acuity on this chart compared to the standard white background chart.
>
> Old normals: Mean 0.57 (s.d. 0.08) log MAR: a loss of almost 6 lines, comparable to the pre-ARM patients.
>
> Young normals: Mean 0.36 log units (s.d. 0.08): the acuity decreased by 3.5 lines compared to 6 lines for the pre-ARM patients.

d. Summary

(1) Pre-ARM or drusen patients with good visual acuity behave the same as old normal observers. Both groups show more losses than the young control group on all charts.

(2) The young normals can be made to perform like the older groups by placing neutral density filters in front of their eyes to decrease the amount of illumination reaching the retina. On average, a 0.63 log unit ND filter causes the visual acuity scores for the young group to be very similar to the older groups. This filter reduces the light to the retina by a factor of 4.25. Can the differences in performance between the older and the younger groups be accounted for completely by the known differences in pupil size and transmission of the ocular media with increasing age? We measured pupil size for all observers and found that on average the younger group had a pupil size of 5.4mm under the conditions of testing while the older groups had 4mm pupils (no difference was found between the pre-ARM and the old normal group). This difference in pupil size will cause 0.25 log units less light to reach the retina of the older observers. In addition, the ocular lens will transmit less light in the older eye. For the incandescent light source used to illuminate the visual acuity charts, we expect that 0.09 log units more would be absorbed by a 70-year-old lens compared to a 25-year-old lens. Thus 0.36 log units less light will reach the retina of the older observers (0.25 pupil +0.09 lens). But we found empirically that the younger observers needed 0.63 log unit filter to perform like the older observers, which suggest that a small but significant portion of the acuity loss found in the older observers with the dark charts cannot be accounted for by less light reaching the retina of the older observers. Instead, these results

suggest that some of the change in performance (about 43%) must be caused by non-optical (probably retinal) changes.

3. LOW VISION READING PERFORMANCE STUDY

We are extending the low vision reading studies begun last year in order to address the parameters of reading performance relating to low vision aid design.

Following the preliminary pilot testing carried out last year, we have substantially modified the experimental set-up (*Figure 16*) in order to more accurately replicate the paradigm used by our consultant, Gordon Legge, Ph.D., with whom we have corresponded on the details of experimental procedure. Our goal is to extend Legge's work to a wider low vision population, especially including those with macular disease, and to explore the interaction of reading performance with a variety of other variables.

The study now beginning addresses the question of minimum window size required for the efficient reading of scanned text - a vital factor for the optimal design of CCTV reading systems. We wish to determine whether Legge's result (that reading speed is unaffected by window sizes greater than four letters) is applicable to the more commonly occurring eye disorders such as macular disease.

The study is being carried out by our new Low Vision Fellow, Patrice Archambault, M.D., who has joined our staff for one year from McGill University.

Figure 16. Experimental Set-up for Low Vision Reading Study

4. HYBRID FRESNEL-CONVENTIONAL MAGNIFIER

The feasibility study for our Fresnel-Conventional low vision reading magnifier is complete. (The concept of this device is to combine the advantages of clarity and high contrast provided by conventional optics with the light weight and wide field of view made possible by Fresnel technology.)

Our conclusions, based on evaluation by Dr. August Colenbrander of our Low Vision Clinic, and our in-house laboratory tests, are that such a device would be useful in reading large materials such as plans, maps, blueprints, etc. Another application is in reading material such as magazines in which text is arranged in columns and interspersed with pictures. The high-definition central field corresponds neatly to column width, while the Fresnel periphery allows rapid and convenient orientation and scanning. Another potential advantage appears to be in eccentric viewing, allowing an aiming point to be established and marked on the Fresnel part of the magnifier.

We concluded that a lens of this design does indeed have potential applications for low vision, and is worth exploring for commercial potential. Inexpensive manufacture would naturally be desirable, and we have found a potential short-cut in this regard. With the help of our consultant, Dr. Wolfgang Wesemann of the University of Hamburg, we have tested a new Fresnel lens of German manufacture which may offer sufficiently high resolution and contrast to obviate the need for the conventional center lens in most applications.

G. INFORMATION DISSEMINATION

1. TECHNOLOGY TRANSFER

a. *Rehabilitation Engineering Service*

Our privately funded fee-for-service program known as the Smith-Kettlewell Rehabilitation Engineering Service is now in full operation, providing custom-made sensory aids to blind rehabilitation clients. The amendments to the Rehabilitation Act enacted by Congress in 1986 inserted the mandate for states to include Rehabilitation Engineering in their vocational rehabilitation services for all clients when appropriate. We provided input into the regulations implementing these changes, which are still in the process of coming into effect. California has appointed a rehabilitation engineer, Jeff Symons, to coordinate these services, using outside resources such as our Rehabilitation Engineering Service. We have established close contact with Mr. Symons and are in the process of expanding our contacts to encompass a regional and national focus.

These developments at the federal and state levels are taking longer than anticipated to come into full effect, and consequently our Rehabilitation Engineering Service has served a smaller than anticipated number of clients. We have, however, delivered a tape tone indexer, an auditory breakout box, three carpenter's levels, and a meter reader, and we have orders for two stud finders and a voltmeter. We have also established a scale of fees acceptable to the State Department of Rehabilitation for expense reimbursement.

b. *California Consortium on Rehabilitation Technology*

We have formed a California Rehabilitation Engineering Consortium together with Rancho Los Amigos REC, Stanford Children's Hospital REC, and the Assistive Devices Center, Sacramento, to provide input to the California State Department of Rehabilitation in the formulation of their plan to implement the federal regulations. This consortium has recently been expanded to include major consumer organizations and other state and private agencies to assist in responding to the other new related piece of federal legislation just enacted. This legislation requires states to form state-wide consortia to compete for new funds for model delivery systems. We are participating with this consortium in an ongoing series of meetings with consumer advocates and state legislative aides with the goal of establishing the optimal model delivery system for rehabilitation technology in California.

c. *Commercialization of Devices*

Another notable achievement of our technology transfer efforts has been the accelerated transfer to commercial production of a number of REC-developed devices. The Smith-Kettlewell Auditory VU Meter, Auditory Oscilloscope, Note-a-Braille, and SKERF-Pad have entered commercial production this year, with transitional assistance provided by our REC. Commercialization is also under way for our Flexi-Formboard and Braille Display. These devices join a growing number of others already in production including the Smith-Kettlewell REC-developed Light Probe, Talking Elevator Module, "Tweedle-Dump," Talking Signs, Receptionist Mat, and "Say When."

d. *Smith-Kettlewell Technical File*

The *Smith-Kettlewell Technical File* (our primary vehicle for providing information to the blind community) has almost reached a balance between subscription income and publishing costs. We anticipate that this goal will be achieved during the coming year.

The existence of the Technical File results in approximately 70 REC-designed sensory aids per year being built by or for readers (according to an earlier survey performed by Lesley Brabyn). The considerable demonstrated value of the publication as a technology transfer vehicle thus augments the REC's other efforts to disseminate the fruits of research to the different target groups. It also enforces discipline in documenting our research projects once completed.

e. *Training Activities*

We have participated in many workshops and seminars designed to increase awareness of sensory aids technology among rehabilitation counselors and other service delivery professionals. For example, several members of our staff are participating on an ongoing basis in the presentation of lectures at San Francisco State University, the Sensory Aids Foundation, and elsewhere to rehabilitation counselors and trainees. A wide range of such addresses and presentations is listed below.

2. PUBLICATIONS, PRESENTATIONS, AND GENERAL INFORMATION DISSEMINATION ACTIVITIES

Special Conference Activities

On September 23 this year we hosted an AER Continuing Education Seminar for special education and rehabilitation professionals in the field of visual impairment. This one-day workshop was designed to improve communication among the various professionals involved in the vision rehabilitation process. It was held in the Smith-Kettlewell conference facilities with the participation of members of our REC staff, Dr. August Colenbrander from our affiliated Low Vision Clinic, and others including Dr. Ian Bailey of the University of California, Berkeley, Low Vision Clinic.

We have also been engaged in collaboration with the Trace Center REC in planning a workshop on the state-of-the-art of computer access for the blind, to be held in Madison, Wisconsin on October 4-7, 1988. Finally, we have begun work on a state-of-the-art conference in vision rehabilitation technology research, to be held at Smith-Kettlewell in 1989.

Presentations

Brabyn, J. Guest Lecture, "Research and Development in Sensory Aid Technology." Sensory Seminar, San Francisco State University, Department of Special Education, December 2, 1987.

Brabyn, J. Session Moderator, "Science and Technology for Blind and Visually Impaired People: Computer Technology, Education and Employment," AFB/FJB International Symposium, "Vision Loss: Everybody's Business," Los Angeles, February 3-6, 1988.

Brabyn, J. Invited Speaker, "New Technology for the Blind: Examples and Issues." Royal Guide Dogs for the Blind Associations of Australia, Conference "The Shape of Services in the Future." Melbourne, March 28, 1988.

Brabyn, J. Session Moderator, "Sensory Aids for the Visually Impaired," RESNA Conference, Montreal, June 1988.

Brabyn, J. "Computer Access Problems of the Future," talk given at Sensory Aids Foundation, Palo Alto, August 19, 1988, and September 16, 1988.

Fowle, T. Workshop on Computer Access by Blind and Visually Impaired Individuals. ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 26, 1988.

Fowle, T. Presentation, "Interfacing Speech Systems to Existing Computers," Sensory Aids Foundation Computer Access Training Program, Palo Alto, June 10, September 23, and October 28, 1988.

Gerrey, W. Invited Presentation to blind high school students on "Science and Electrical Engineering as Career Options," statewide inter-agency sponsored career day, Ogden, Utah, October 28, 1987.

Gerrey, W. Conducted three classes at the Lawton Elementary School, San Francisco, testing the final design of a six-session electricity and magnetism course for blind children, February 9 and 23, and March 1, 1988.

Gerrey, W. Conducted San Francisco State University Class Session on Rehabilitation Engineering, February 29, 1988.

Gerrey, W. Presentation, "Sensory Assistive Devices for People with Disabilities." Annual Scientific Conference of the California Society of Physical Medicine and Rehabilitation, "What's New in Rehabilitation Engineering?", San Jose, California, May 6, 1988.

Gerrey, W. Presentation Series, "Introducing the SKERF-Pad Touch-Screen System," Sensory Aids Foundation Computer Access Training Program, Palo Alto, California, June 9, September 22, and October 27, 1988.

Gerrey, W. Presentation, "Word Processing with a Representative Audio Screen Using the AudioData as a Model," Sensory Aids Foundation Computer Access Training Program, Palo Alto, June 23, 1988.

Gerrey, W. Gave invited testimony regarding access problems before the State Attorney General's Commission on Disability, Oakland, California, September 9, 1988.

Gilden, D. "An Overview of Sensory Aids for the Blind Developed at the Smith-Kettlewell Rehabilitation Engineering Center," Nepean College of Advanced Education, Sydney, Australia, November 23, 1987.

Gilden, D. "An Overview of Sensory Aids for the Blind Developed at the Smith-Kettlewell Rehabilitation Engineering Center," Lady Rowallan School for the Deaf, Hobart, Tasmania, Australia, November 26, 1987.

Gilden, D. "An Overview of Sensory Aids for the Blind Developed at the Smith-Kettlewell Rehabilitation Engineering Center," University of Tasmania, Hobart, November 27, 1987.

Gilden, D. "An Overview of Sensory Aids for the Blind Developed at the Smith-Kettlewell Rehabilitation Engineering Center," Auckland College of Education, Auckland, New Zealand, December 2, 1987.

Gilden, D. "'Dexter,' A Mechanical Fingerspelling Hand for Deaf-Blind Users," Bay Area Audiological Society, San Francisco, California, April 19, 1988.

Gilden, D. Invited Speaker, "Technology Needs of Blind Consumers," IBM Special Needs Initiatives and Programs, Hawthorne, New York, May 9, 1988.

Gilden, D. "High-Tech Toys for Back-to-Basics," ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 26, 1988.

Gilden, D. "Navigation Device for the Blind," ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 27, 1988.

Gilden, D. "From Toys to Tools: Sensory Aids from Smith-Kettlewell," Association for the Employment and Rehabilitation of the Blind and Visually Impaired, Montreal, July 11, 1988.

Loughborough, W. Workshop on Computer Access by Blind and Visually Impaired Individuals. ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 26, 1988.

Tyler, C. Guest Lecture, "Development and Implementation of the Sweep Visual Evoked Potential Procedure (VEP) with Infants; Contrast Sweep and Clinical VEP Techniques." Sensory Seminar, San Francisco State University, Department of Special Education, October 7, 1987.

Publications

Brabyn, J.A. "Smith-Kettlewell Rehabilitation Engineering Center Progress Report to 1988." Veterans Administration Rehabilitation R&D Progress Report, 1988.

Brabyn, J.A. "Assistive Devices for the Blind and Visually Impaired." Encyclopedia of Medical Devices and Instrumentation, J. Webster, Ed., New York: John Wiley & Sons, 1988, Vol. 1, 425-438.

Brabyn, J. and Brown, B. "Mobility and Low Vision: Identifying the Problems and Non-Problems. In preparation.

Brown, B. and Brabyn, J.A. "Mobility and Low Vision: A Review." Clinical & Experimental Optometry, 70.3: May/June 1987, 96-101.

Day, S.H., Orel-Bixler, D.A. and Norcia, A.M. Abnormal acuity development in infantile esotropia. Invest. Ophthal. Vis. Sci., 1988, 29, 327-329.

Day, S.H. and Norcia, A.M. "Photographic screening for factors leading to amblyopia," Amer. Orthoptic J., 1988, 38, 51-55.

Gilden, D. "Final Report - NASA/CSUN Planning Committee Meeting of September 28-29, 1987," held at Casa Sirena Hotel, Oxnard, California, published October 30, 1987.

Hamer, R.D., Norcia, A.M., Tyler, C.W. and Hsu-Winges, C. "The development of monocular and binocular VEP acuity." Vision Res. In press.

Norcia, A.M., Tyler, C.W., Hamer, R.D. "Development of Contrast Sensitivity in Human Infants." Investigative Ophthalmology and Visual Science, 1988, 29, 44-49.

Norcia, A.M., Tyler, C.W., Piecuch, R., Clyman, R., Goldstein, J. "Visual Acuity Development in Normal and Abnormal Preterm Human Infants." Journal of Pediatric Ophthalmology and Strabismus, 1987, Vol. 24, No. 2, 70 - 74.

Norcia, A.M., Tyler, C.W., Hamer, R.D. and Wesemann, W. Measurement of spatial contrast sensitivity with the swept contrast VEP. Vision Res. In press.

Norcia, A.M., Tyler, C.W. and Hamer, R.D. Development of contrast sensitivity in the human infant. Vision Res. In press.

Norcia, A.M., Tyler, C.W., Piecuch, R., Clyman, R. and Goldstein, J. Visual acuity development in normal and abnormal preterm human infants J. Ped. Ophthal. Strabismus, 1987, 24, 70-74.

Norcia, A.M., Tyler, C.W. and Hamer, R.D. High visual contrast sensitivity in the young human infant. Invest. Ophthal. Vis. Sci., 1988, 29, 44-49.

Orel-Bixler, D.A. and Norcia, A.M. Differential growth of acuity for steady-state pattern reversal and transient pattern onset-offset VEPs. Clin. Vis. Sci., 1987, 2, 1-9.

Wesemann, W., Norcia, A.M. and Allen, D. Theory of knife-edge photorefraction: astigmatic eyes. J. Opt. Soc. Amer. In press.

Published Proceedings

Brabyn, J.A. "Electronic Braille Technology for the Blind." Proceedings, IEEE/EMBS 9th Annual Conference, Boston, MA, November 14-16, 1987, 1791-2.

Fowle, T., Gerrey, W., and Brabyn, J. "A Universal Job Instrumentation System for the Blind ("Flexi-Meter")," Proceedings, ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 1988, 212-13.

Gerrey, W., Fowle, T., Brabyn, J., and Loughborough, W. "Achieving Access and Fair Accommodation in a Computerized Workplace." Background paper for Planning Workshop on Access to Computers and Electronic Devices by Blind Individuals, Trace R&D Center, University of Wisconsin-Madison, October 4-7, 1988.

Gilden, D. "High-Tech Toys for Back-to-Basics," Proceedings, ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 1988, 210-11.

Loughborough, W. "Establishing Parameters for a Screen Reader," Proceedings, ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 1988, 208-9.

Milner, R. and Gilden, D. "Navigation Device for the Blind," Proceedings, ICAART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 1988, 214-15.

Exhibits

Gerrey, W., Gilden, G. and Williams, J. Exhibit, "Educational and Vocational Aids for the Blind." Joint Conference of the California Transcribers and Educators of the Visually Handicapped and the National Braille Association, Inc. - Western Region, Irvine, California, March 17-19, 1988.

Gerrey, W. Guest Exhibitor, "Smith-Kettlewell Computer Accessories," Bay Area Blind Computer Users' Group, Berkeley, California, October 20, 1987.

Gerrey, W. and Williams, J. Exhibit for "Music and Scientific Careers," California School for the Blind, Fremont, California, November 14, 1987.

Interviews

Gerrey, W., Fowle, T., and Williams, J. Appeared in local TV Channel 5 program "Tech Trek," March 8, 1988.

Programs Organized

Gilden, D. Disabled Children's Computer Group Meeting on Computer Music and Disabled People, May 12, 1988.

Gilden, G. Workshop on Computer Access by Blind and Visually Impaired Individuals. IC-AART-88, RESNA Conference on Rehabilitation Engineering, Montreal, June 26, 1988.

Panels

Brabyn, J. Panel Member, AER Continuing Education Seminar, Smith-Kettlewell Eye Research Institute, San Francisco, September 23, 1988.

Fowle, T. Panel Member, "Rehabilitation Engineering and Its Relationship to Employment Development," Lighthouse for the Blind, San Francisco, January 27, 1988.

Gerrey, W. Panel Member, Blind Babies Foundation's Parent Workshop, Fremont, California, June 17, 1988.

Conference Participation

Gilden, D. Participant, NASA/CSUN Conference on Recruiting Disabled Employees, Los Angeles, May 24-27, 1988.

Advisory Groups and Professional Organizations

Brabyn, J. Chairman, NIH Special Study Section for Small Business Innovative Research, 1986 to present.

Brabyn, J. Member, Scientific Advisory Board, VA Rehabilitation Research and Development Service, 1985 to present.

Brabyn, J. Consulting Member, National Advisory Council, Mississippi State University Research and Training Center on Blindness and Low Vision, 1982 to present.

Brabyn, J. Member, Meetings Committee, RESNA, 1988.

Brabyn, J. Member, various special review panels for NIDRR and NEI, 1980 to present.

Gerrey, W. Member, Computer Center Advisory Committee, Lighthouse for the Blind, San Francisco, March 24, May 19, and July 28, 1988.

Gerrey, W. Member, San Francisco Department of Public Works Facilities Advisory Task Force, May 1988 to present.

Gilden, D. Member, Board of Directors, Disabled Children's Computer Group, Berkeley, California.

Gilden, D. Co-Chairman, Special Interest Group on Sensory Aids, RESNA, the Association for the Advancement of Rehabilitation Technology, 1987-88 and 1988-89.

Gilden, D. Member, Board of Directors, San Francisco International Toy Museum.

Gilden, D. Member, Advisory Committee for Product Design, Apple Computer, Preschool Division.

Awards

Brabyn, J. William A. Kettlewell Chair, August 15, 1988.

Gilden, D. William A. Kettlewell Chair, August 15, 1988.

REC STAFF

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Ann Lewis
Secretary

Charlene Keh
General Office Assistant

Joan Dalla
Secretary (to March 1988)

Betty Graham
Secretary (April to July 1988)

APPENDIX:

MOBILITY STUDY PROTOCOL

In the protocol that follows, the subject and the experimenters are identified by the initial letters of their last names. The protocol also includes statements labeled as comments that have been added to clarify statements made by the subject or to indicate the need for clarification, to draw the reader's attention to the significance of statements made by the subject, and to explain scoring decisions.

The route on which subjects were observed went south from the front door of Smith-Kettlewell to the corner of Webster and Clay, west along the north side of Clay to Fillmore, south along the east side of Fillmore to Bush, east along the north side of Bush to Buchanan, north along the west side of Buchanan to Clay, and west through the hospital grounds on the closed segment of Clay to Webster. All subjects were familiar with the segment of the route from Smith-Kettlewell to the corner of Fillmore and Bush, and all of the subjects had little or no familiarity with the segment of the route from the corner of Fillmore and Bush back to Smith-Kettlewell.

<u>Subject: "C"</u>   <u>Experimenters: John Brabyn and Emerson Foulke</u>   <u>Date: November 1987</u>

C: We go out here and I'm going to look for this echoey garage, and I hit this wall here. 1m(sa)p(a.ve) 2p(c)

B: You veered to the left into the garage.

Comment: C's memory of the garage is probably evoked, not by an environmental cue, but by an associative cue. He verifies his expectation by listening for the echo. Because he veers as he passes the entrance to the garage, he hits the garage wall with his cane.

C: And now we've got the wall, so I'll go up here and hit this crossing here. 3p(a) 4m(s)p(a.ve)p(c.ve.ca) 5m(dr)

Comment: C is referring to the garage wall that is parallel to the sidewalk and on his left. He maintains his position on the sidewalk by monitoring the sound reflected from the garage wall. He remembers this situation and expects the garage wall to come to an end shortly. He verifies this expectation by listening and by finding the end of the wall with his cane. Having found the end of the wall with his cane, he knows where he is in relation to the curb he will encounter shortly, and this knowledge makes cognitive anticipation possible. His course, as he turns out toward the street, is a remembered course, and he is not guided, at least for a few feet, by perceptual feedback.

B: How did you determine where to turn, where to cross?

C: Being familiar, I waited until I got to the end of that wall and then came out.

B: Did you detect the end of the wall with your cane tip, or did you hear it?

C: I was pretty much using the cane. However, I did hear it, too.

C: Now this street, I like to cross it via aggressiveness. 6p(a)

F: How did you decide when to cross?

C: There wasn't much happening, and I know that this is a know-about sort of thing, where if you get out there and are seen, you'll probably make it alive.

Comment: Another indication of a risk-taking policy. C bases his crossing decision on auditory information, but he is willing to settle for less than certainty.

C: I also did make a kind of outward arc to try to hit this intersection, I mean the curb, toward the outside of it. 7m(dr) I like to do that. Sometimes there's curb cuts, but I hate to get tangled up in whatever might be on the inside part -- poles and whatnot.

Comment: By dead reckoning, C determines a course which should bring him to the part of the curb he wants to hit. By making an outside arc, C increases the risk of missing the sidewalk on the other side, and walking in the parallel street, but he reduces the risk of getting tangled up in the poles and other objects he might encounter if he were off a little in the opposite direction.

F: What was the name of the street you just crossed?

C: I just crossed Webster Street. Now I am going to face west and head off down Clay Street.

C: And there's a pole, and so I've got to get over toward the inside part of the sidewalk. 8i[p(c)m(g)]

Comment: C finds the pole with his cane. Finding the pole evokes the remembered generalization that poles of this type are usually near curbs. The inductive inference of which this generalization is the result took into account numerous occasions in the past on which poles of this type were close to the curb. It follows that the pole he has just found is near the curb. Because he is near the pole, he must also be near the curb, and he decides to move to the right, away from the street, in order to avoid, as he walks, the poles and other articles of street furniture that are usually located close to curbs. The generalization that C applies to the present situation is probably the product of inductive reasoning that took place some time in the past. C probably stored the generalization in memory and recalled it on this occasion. In my scoring, I am not distinguishing between remembered inferences and inferences that occur in the present. However, this might be a useful distinction.

C: Now the cane is telling me that we have some dirt and so on on the left. 9p(c) My arm brushed a pole. 10p(d)

C: I get some auditory information off the dripping / off these buildings. 11p(a)

C: Now Clay Street has these drops off to the right, so that you not only have a building there, but you have the sense that the sidewalk falls away, and sometimes that adds quite a bit of echo, and it also / well, not quite a bit of echo, but some / it's weird. It's an unusual sounding thing. 12p(a)

Comment: From what C has said, it is not clear to me just what situation he is describing, but, in any case, he is monitoring the sound reflected from the buildings on his right to maintain his position on the sidewalk.

C: Obviously we have hammering coming up on the right. 13p(a)

Comment: At this point, the sound of hammering on metal is loud enough to mask other useful sounds.

C: And there's an obstacle on the right, which I detected simultaneously with the cane and heard it. It is pallets or something. 14p(a) 15p(c)

B: Yes, that's construction.

C: And now the rain introduces a lot more noise. 16p(a)

Comment: The sound made by falling rain is an effective masking sound that may hide sounds C would like to hear.

C: Oops, I'm hung up by something. 17p(c)

SCORING SUMMARY -- FAMILIAR ROUTE

1m(s)p(a.ve) Specific memory of garage wall; auditory perception of garage wall in order to verify memory.

2p(c) Cane perception of garage wall.

3p(a) Auditory perception of garage wall on left, in order to maintain sidewalk position.

4m(s)p(a.ve)p(c.ve.ca) Specific memory of imminent end of garage wall; auditory perception of end of garage wall in order to verify memory; cane perception of end of garage wall in order to verify memory; perception of end of garage wall enables cognitive anticipation.

5m(dr) Specific memory of distances and headings for course terminating at particular section of curb on far side of street.

8i[p(c)m(g)] Inference: parallel curb too close for comfortable walking. Evidence: auditory perception of pole; general memory of where such poles are usually found.

9p(c) Information about character of surface provided by cane.

10p(d) Informed of obstacle by dermal stimulation.

11p(a) Reflected sound used to maintain sidewalk position.

12p(a) Reflected sound, used to maintain sidewalk position, also provides hint of irregular character of area to side of sidewalk away from street.

13p(a) Hammering on metal identified by the sound it makes.

14p(a) Obstacle located by reflected sound.

15p(c) Obstacle located by cane.

16p(a) Sound of rain produces auditory interference.

17p(c) Obstacle located by cane.

EXPLANATION OF SCORING SYSTEM

A pedestrian's purposeful movement is the consequence of decisions to move, and these decisions are mediated by information. The spatial information used by a pedestrian includes spatial facts that are the immediate results of perception, as when a sighted pedestrian knows that a curb is a few feet ahead because he sees it, and spatial facts that are the remembered results of perception, as when a blind pedestrian, having perceived the partial obstruction of a path by a sign post, remembers that fact on a subsequent occasion.

A remembered fact may be the result of a communication, as when a blind pedestrian tells his blind friend that the sidewalk becomes level in front of the entrance of the restaurant to which his friend is going.

A remembered fact may also be a generalization. Though the remembered fact is the result of experience in some other situation, it is assumed to be true for the current situation as well, because the current situation is similar to the situation in which the fact was learned. This is an important distinction because, although the spatial information they can acquire by direct perception is often inadequate, blind pedestrians are able to predict many of the features of unexperienced spaces by drawing on their knowledge of the reiterations of spatial features that characterize manmade environments. Blind subjects should show more dependence on generalizations of this sort when traveling unfamiliar routes.

The spatial information used by pedestrians also includes conclusions that are reached after considering the available evidence; that is, inferences. The evidence on which inferences are based may include spatial facts that are the immediate results of perception, spatial facts that are the remembered results of earlier experience in the current situation, spatial facts that are generalizations, spatial facts that are the results of communication, and spatial facts that are, themselves, inferences.

The score assigned to each assertion is enclosed in brackets if it records either a perception or a memory. If it records an inference, it is enclosed in braces.

An assertion is scored *P* (perception) if it reports a spatial fact that is the immediate result of perception. For instance, if a sighted subject knows that a curb is approximately ten feet ahead because he sees the curb, the subject's assertion that there is a curb ten feet ahead receives the score of *P*.

When *P* is scored, it is qualified in one or more ways, and its qualifiers are enclosed in parentheses. If the subject reports hearing something, an *A* (auditory) is added to the score. If the subject reports smelling something, an *O* (odor) is added. If the subject reports the manual exploration of something, an *H* (haptic) is added. If information is supplied by the muscle sense, as when a subject identifies a spore by the particular way its door resists opening when the door handle is pulled, a *K* (kinesthetic) is added. If the subject reports feeling the sun, wind, rain, etc., a *D* is added. There are two kinds of proprioception to be distinguished. If the subject reports the feel of the surface underfoot, an *F* (foot) is added. If the subject reports discovering something by touching it with his cane, a *C* (cane) is added. A perception may also be an observation made to verify an earlier perception, as when a blind pedestrian touches an object with his cane to verify the auditory impression of its location. In this case, *C* (cane) is followed by *V*, and the letter that labels the perception being verified. For example, if a subject hears the sound reflected from a pole and touches the pole with his cane to verify the auditory perception, the score [p(acva)] is assigned.

An assertion is scored *M* (memory) if the spatial fact it reports is the remembered result of a perception, a communication, or an inference. Thus, if a blind subject reports that a mailbox is immediately to the left of the curb cut on which he is standing, because he remembers the earlier haptic perception of the mailbox, his score includes *M* for the remembered mailbox.

When *M* is scored, it is qualified in one or more ways, and its qualifiers are enclosed in parentheses. If a remembered fact is a feature of the current space that was perceived on an earlier occasion, the qualifier *S* (specific) is added.

Sometimes, although remembered information acquired on some prior occasion enters into the decision of the moment, it is not possible to relate the evoked memory to the perception of any specific feature of the current space. This would occur when, for example, a blind pedestrian makes use of his knowledge that a certain intersection is not controlled by traffic lights to make a decision about when to cross a street, but cannot point to any specific feature of the current situation that has evoked the memory. Remembered facts of this sort are probably evoked by associative links with other items of remembered information, such as the knowledge that the intersection in question is the one that comes up next in a remembered sequence of intersections. In such a case, the qualifier *A* (association) is added.

If the evoked memory is of other situations that are like the present situation in some degree, so that prediction of features of the current space is possible, even though the current space has not been experienced before, the qualifier *G* (generalization) is added.

Occasionally, a subject's assertion will indicate that his movement, at least for a short distance, has been guided by remembered headings and distances, learned during earlier practice on the current route, rather than by sensory feedback. When this is the case, the (M) component of the score assigned to the subject's assertion is qualified by *DR* (dead reckoning).

Sometimes a perception is significant, not in its own right but because of its relationship to a memory. When this is the case, the *P* that is recorded is included inside the brackets that enclose the *M* to which it is related. As in the case of other perceptions, these perceptions receive qualifiers which indicate the senses involved. There are, in addition, qualifiers which apply only to perceptions of this sort.

If a perceived feature of the current space functions as a redintegrative stimulus that retrieves a spatial fact from memory, the *P* is qualified by *R* (redintegration). Thus, if a subject knows that the left turn into a certain building is a few feet ahead, his assertion is scored [m(s)p(fr)].

Sometimes a blind pedestrian touches an object with his cane, listens for an echo, or makes some other observation, not to acquire new information but rather to verify an expectation concerning the location of some remembered feature of the space in which he is operating. Of course, a spatial feature whose location is thus verified is a landmark. If an observation of any kind has been made for the purpose of verifying an expectation, a *VE* (verify expectation) is added. If, for instance, a blind pedestrian touches a remembered pole with his cane to verify its presence and position, his assertion is scored [m(s)p(cve)].

An assertion is scored *I* for inference if the spatial fact it reports is deduced from the available evidence. The evidence may be the immediate result of perception or the remembered result of perception or both. When *I* is included, the score also reflects the perceptual and memorial components of the inference. For instance, if a blind subject concludes that an intersection is controlled by traffic lights because he hears the sounds made by moving traffic on the parallel street and by halted traffic on the cross street, followed by the sounds made by moving traffic on the cross street and by halted traffic on the parallel street, an *I* (inference) is scored. The perceptual and memorial components of the inference follow the *I*, and are segregated in the manner already described.

By making the distinction between spatial facts that are remembered or inferred, and spatial facts disclosed by direct perception, it will be possible to evaluate the hypothesis that the space in which the blind pedestrian performs the mobility task is, to a considerable degree, a remembered space and a space inferred from evidence at hand, whereas the space in which the sighted pedestrian performs the mobility task is, to a considerable degree, a space that is known immediately by perception.

To say that a spatial fact is an inference is to say that it has been established not by observation but by deduction from the available evidence. Therefore, if blind pedestrians must make greater use of inference than sighted pedestrians in order to perform the mobility task, it follows that they must depend more heavily than sighted pedestrians on memory in order to perform that task. Accordingly, performance of the mobility task by blind pedestrians is more strongly influenced than performance of the same task by sighted pedestrians by pitfalls such as distorted memorial representations, incomplete memorial representations, memory lapses and the like, that beset memory.

Orientation involves inference. The traveler, blind or sighted, who maintains orientation is reaching conclusions about where he is in a known space by drawing inferences from the available perceptual and memorial evidence. Much of the evidence involved in inference consists of perceived spatial features that serve as landmarks. Because the reach of the perceptual systems on which blind pedestrians depend for spatial knowledge is so much smaller than the reach of the perceptual system on which sighted pedestrians primarily depend for spatial knowledge, the space in which blind pedestrians are oriented is usually very much smaller than the space in which sighted pedestrians are oriented. Consequently, blind pedestrians must perceive many more landmarks and make many more inferences than sighted pedestrians in order to maintain orientation.

The scores of each kind are counted, and these counts are given at the end of the protocol.

In the protocol, the subject and the experimenters are identified by the initial letters of their last names. The protocol also includes statements labeled as comments that have been added to clarify statements made by the subject or to indicate the need for clarification, to draw the reader's attention to the significance of statements made by the subject, and to explain scoring decisions.

The route on which subjects were observed went south from the front door of Smith-Kettlewell to the corner of Webster and Clay, west along the north side of Clay to Fillmore, south along the east side of Fillmore to Bush, east along the north side of Bush to Buchanan, north along the west side of Buchanan to Clay, and west through the hospital grounds on the closed segment of Clay to Webster. All subjects were familiar with the segment of the route from Smith-Kettlewell to the corner of Fillmore and Bush, and all of the subjects had little or no familiarity with the segment of the route from the corner of Fillmore and Bush back to Smith-Kettlewell.

NOTES